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ABSTRACT

Title of Dissertation: ANTECEDENTS AND BENEFITS OF SUPPLY CHAIN TECHNOLOGY ADOPTION

Kirk Alan Patterson, Doctor of Philosophy, 2002

Dissertation directed by: Dr. Thomas M. Corsi, Co-chairman
Dr. Curtis M. Grimm, Co-chairman
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As business organizations face a more complex and competitive environment than ever before, innovation of organizational products and processes is essential for generating and sustaining a competitive advantage. Two areas of innovation that have considerable potential to impact organizational performance are technology adoption and supply chain management. Innovative information technologies have the capacity to impact operational procedures and structures, firm strategy, communication exchange, buyer-supplier relationships and bargaining power and have become so pervasive that most managers consider them to be a requirement for doing business in today's competitive marketplace. Supply chain management integrates logistics activities within and between firms in the supply chain.

This dissertation attempts to merge the two streams of research and examine the organizational and environmental factors leading to supply chain technology adoption as well as the resulting benefits. For the purposes of this research, supply chain technology includes a wide range of technologies that enhance data management and information exchange within and between organizations of the supply chain. The benefits examined include both logistics performance measures such as inventory levels, logistics costs, and cycle time as well as integration measures such as information sharing and coordination of logistics activities.

The model was tested using a survey instrument developed in collaboration with a group of supply chain consultants and professionals. The results highlight the current state of supply chain technology employment and suggest five of the seven hypothesized factors play an important role in predicting adoption of supply chain technologies. The results also indicate significant benefits have been achieved by responding organizations.

ANTECEDENTS AND BENEFITS OF

SUPPLY CHAIN TECHNOLOGY ADOPTION

by

Kirk Alan Patterson

Dissertation submitted to the Faculty of the Graduate School of the
University of Maryland, College Park in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy
2002

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Dr. Thomas Corsi, Co-chairman
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PREFACE

The views expressed in this dissertation are those of the author and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the U.S. Government.

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1. INTRODUCTION

"*The use of technology and effective information management systems is potentially the greatest destabilizing force in all distribution channels.*" (Lusch et al. 1993; p. 25)

Business organizations today face a more complex and competitive environment than ever before (Ellram, 1991; Srinivasan et al., 1994; Porter and Stern, 2001). As trade barriers crumble and less developed countries enter the competitive marketplace, firms now confront a greater number of competitors able to introduce new products and services faster and cheaper than ever before (Garten, 1998). The ever-expanding capabilities of information technology with the concomitant reduction in investment costs allow capital and information to flow almost instantly throughout many parts of the world. Furthermore, as consumers have become more discriminating and demanding (Ellinger et al., 1997), product life cycles have been shortened, forcing firms to contract time to market periods and provide higher levels of customer service and customized products. Consequently, most industries and firms have entered into a "hyper-competitive" marketplace marked by an increase in competition, uncertainty, and complexity (D'Aveni, 1994, D'Aveni 1999; Merrifield, 2000).

In this environment, innovation of organizational processes and products (D'Aveni, 1994; Veliyath and Fitzgerald, 2000) is critical. Innovation has generally been defined as an idea, product, program or process that is new to the adopting individual or organization (Zaltman et al., 1973). Merrifield (2000; p.42) argues, "The most viable strategy for both generating and sustaining a competitive advantage has become one of

both continuous innovation and corporate renewal." In the past, business organizations focused on reducing costs and improving quality to gain a competitive advantage. However, today, "companies must be able to innovate at the global frontier... and create and commercialize a stream of new products and processes that shift the technology frontier, progressing as fast as their rivals catch up" (Porter and Stern, 2001; p.28).

One area of innovation that has been the focus of significant research is technology adoption. Innovative information technologies have the capacity to impact firm strategy, communication exchange, operational procedures, buyer-supplier relationships and bargaining power (Bowersox and Daugherty, 1995; Lewis and Talalayevsky, 1997; Williams et al. 1997; Clemons and Row, 1991). Cash and Konsynski (1985) claim information technology increases organizational productivity, flexibility, and competitiveness. Daugherty et al., (1995) suggest the greatest advantage of information systems is that they stimulate the development of interorganizational networks. Information systems have become so pervasive that many researchers consider them to be a requirement for doing business in today's competitive marketplace (Clemons and McFarlan, 1986; Dawe, 1994; Rogers, 1990; Rogers et al., 1992).

With extensive theoretical justification and forty percent of new capital equipment investment in the US allocated to information technology (Hitt and Brynjolfsson, 1996), executives obviously expect significant organizational benefits. However, empirical studies have reported contradicting results concerning the impact of technology on organizational performance (Brynjolfsson, 1993). During the late 1980s, most productivity studies suggested that computers did not enhance productivity and thus the term "productivity paradox" was popular in trade and academic journals (Brynjolfsson,

1993). As studies in the 1990s began focusing on firm level effects, results began suggesting that information technology positively impacted revenue and firm output (Brynjolfsson and Hitt, 1996; Dewan and Min, 1997). For example, Droge and Germain's (2000) review of the Electronic Data Interchange research suggest that EDI was consistently found to improve customer service and lower cost. Still, one recent study by the London School of Economics of 659 CEOs found only 25 percent of executives were satisfied with the results of their information technology investments (Compass Group, 1999).

Another organizational innovation that has received considerable attention in both the trade press and academic literature is supply chain management. Many scholars and executives see supply chain management, or the integration of logistics activities within and between firms in the supply chain as an important organizational approach that enhances information exchange between trading partners (Menon and Varadarajan, 1992) and improves organizational competitiveness (Stank and Lackey, 1997). In fact, a recent survey found that ninety-one percent of manufacturers in North America believe supply chain management is very important or critical to their company's success (Thomas, 1999).

Supply chain management is so critical to firm success because of the central role logistics plays in organizational operations. It has been estimated that logistics accounted for roughly 10 - 17% of the US Gross Domestic Product in 1996, with expenditure estimates ranging from almost 800 billion to 1.3 trillion dollars (Bowersox and Calantone, 1998; Winston, 1999).

Though more than ninety percent of manufacturers believe supply chain management is very important, only two percent rate their management of supply chain activities as "world class" (Thomas, 1999). Perhaps the main reason for this extreme disparity is the complexity of integrating logistics operations between firms as well as successfully integrating activities within firm boundaries. Successful supply chain management requires effective management of strategic alliances (Monczka et al. 1998; Whipple and Frankel, 2000) as well as extensive data management capabilities and advanced interorganizational information systems to enable greater information exchange (Gustin et al., 1995; La Londe and Masters, 1994; Bowersox and Calantone, 1998; Stank et al., 1999). Some authors suggest that information technology is the single, most important factor to logistics and supply chain management improvement (Dawe, 1994) while thirty-four percent of logistics executives rank technology as the most important factor in improving logistics capabilities (Bradley et al. 1999).

Clearly, researchers and practitioners recognize the importance of both technology and supply chain management to organizational performance and competitiveness. In this study, we will attempt to merge the two streams of literature and examine supply chain technology adoption. For the purposes of this research, supply chain technology will be considered to include a variety of technologies that enhance supply chain data management and information exchange within and between organizations of the supply chain. The list of technologies examined range from the widely prevalent bar-coding technology to much newer application systems such as Enterprise Resource Planning System (ERP) and Supply Chain Planning Systems (SCP).

The goal of this research is to develop a more comprehensive understanding of the environmental and organizational antecedents of supply chain technology adoption as well as an in-depth understanding of the resulting organizational benefits. This research extends previous studies on technology adoption and contributes to the supply chain literature in a variety of ways. First, much of the early research examining technology adoption used capital investment or expenditure as the measure of technology adoption (Hitt and Brynjolfsson, 1996). This research focuses on supply chain technology and uses survey data to identify the types of technology responding firms have adopted and implemented. Second, most studies involving the supply chain and technology adoption have focused primarily on electronic data interchange (EDI). Of the few studies that have taken a broader view of logistics technology, most have included only warehouse automation technologies (Dadzie and Johnston, 1991; Dadzie et al., 2000) or addressed software in only a very general way (Germain et al., 1994). This study will expand the scope of technology adoption to include a variety of intra- and inter-organizational technologies and software applications. Third, several past studies concentrated on the retailer-distributor supply chain link to examine the effectiveness of inter-organizational information systems (Ahmad and Schroder, 2001). In this study, business organizations from throughout the supply chain will be included. Fourth, manufacturers from a variety of industries will be examined. According to Ahmad and Schroder (2001), many studies have focused on a single organization or industry. Thus, the generalizability of this study will be enhanced over previous studies. Furthermore, the rapid pace of change in information technology experienced over the past decade continues to accelerate (Benamati and Lederer, 2000) and new technologies that specifically impact supply chain

activities are continually being introduced. This study will consider a wide range of supply chain technologies that include the latest applications and software. Finally, there have been few empirical studies addressing the effect of technology on the level of integration between supply chain members (Kraut et al., 1998; Kekre and Mukhopadhyah, 1992). This research will attempt to ascertain managers' perceptions of the impact of technology on the degree of integration between organizations.

In summary, the key factors influencing supply chain technology adoption and the resulting benefits will be examined using a survey instrument developed in collaboration with a group of supply chain consultants. The factors examined include both organizational characteristics of the firm as well as environmental conditions faced by the organization. The benefits of technology adoption examined in this research include the degree of improvement to supply chain integration as well as improvements to organizational logistics performance.

This chapter highlights the importance of innovation to organizational performance in this hyper-competitive marketplace. Organizational changes such as the adoption of new technologies and integration of supply chain activities have been theorized and sometimes found to significantly impact organizational performance. This study attempts to expand our understanding of the factors motivating organizations to adopt new technologies and the resulting organizational benefits.

Chapter two provides an extensive review of the literature relating to technology adoption, supply chain management, and transaction cost economics. Chapter three focuses on the theoretical model and the specific hypotheses tested in the study. Chapter four presents and discusses the methodology and data used to test the research

hypotheses. The results and a discussion of them follow in chapter five. Finally, chapter six closes with conclusions and implications of this research effort.

2. LITERATURE REVIEW

As competition has intensified because of globalization of markets (Garten, 1998) and continually improving and expanding technologies (Clemons et al, 1993), businesses understand the necessity to continually innovate processes and products and to reduce time to commercialization (Merrifield, 2000; Lovelace et al., 2001). Innovation has thus become a major business challenge (Tornatzky and Fleischer, 1990). According to Porter and Stern (2001, p.28) "Innovation has become the defining challenge for global competitiveness." Consequently, innovation has received much attention in both trade and academic journals. Two organizational innovations that will be the focus of this study are technology adoption and supply chain management.

Supply chain management is recognized as one approach to confront the hyper-competition facing many firms today (Merrifield, 2000). An integrated supply chain linking suppliers, manufacturers, distributors and retailers attempts to streamline the many processes from raw materials to customer delivery of the finished product. According to Ahmad and Schroeder (2001), two areas of supply chain management currently receiving significant attention are the establishment and maintenance of information links between trading partners of the supply chain and the reduction of response time throughout the chain.

A variety of theoretical frameworks have been used as a basis for studying the implementation and impact of interorganizational information systems. For example, the social exchange theory focusing on the socio-political factors of power, dependence, and

trust between partners has been used to examine the adoption of interorganizational information systems such as EDI (Premkumar and Ramamurthy, 1995; Premkumar et al., 1997; Hart and Saunders, 1998). Other studies have examined the benefits of EDI adoption using the resource-based view of the firm, organization theory, and transaction cost economics (Clemons and Row, 1989; Srinivasan et al., 1994; Bensaou and Venkatraman 1995). This study will attempt to incorporate applicable aspects of both social exchange theory and transaction cost economics in the examination of antecedents and benefits of supply chain technology.

In this section, the relevant literature addressing theory and the latest findings on innovation adoption, supply chain management and prior studies integrating supply chain management and technology adoption is presented.

2.1 Technology Adoption

Innovation adoption literature provides an important base from which to begin examining supply chain technology adoption. There has been a great deal of research on innovation that spans diverse fields such as sociology, engineering, marketing, communication, and organizational behavior (Rogers, 1995). Innovation comprises a wide variety of actions including "…a new product or service, a new production process technology, a new structure or administrative system, or a new plan or program pertaining to organizational members" (Damanpour, 1991; p.556). Damanpour (1991; p.556) defines innovation as "…adoption of an internally generated or purchased device, system, policy, program, process, product, or service that is new to the adopting organization."

Categories of innovations include distinctions such as radical versus incremental innovations (Dewar and Dutton, 1986) and technical versus administrative innovations (Damanpour and Even, 1984). Rogers (1995) classified innovation and diffusion research into eight broad categories: earliness in knowing about adoption, rate of adoption and innovation attributes, innovativeness of members, opinion leadership, diffusion networks, rate of adoption in different social systems, communications channel use, and consequences of innovation. Organizational technology adoption has been an important focus of study within this literature (Damanpour, 1991).

Kwon and Zmud (1987) reviewed prior innovation research and classified variables that potentially influence technology adoption into five broad categories: individual, task-related, innovation-related, organizational, and environmental characteristics. Individual factors include variables such as age, education and job tenure and are generally more influential in individual adoption of technology. Task factors relate to aspects of specific tasks affected by innovation such as task variety, task autonomy and responsibility (Premkumar et al., 1997; Grover, 1993) and may be important when focusing on individual technologies. Innovation characteristics include perceived variables of the technology such as cost, complexity, relative advantage and compatibility. Again, these are important variables to consider when studying a single technology but difficult to measure when considering a group of technologies with differing characteristics. Organizational factors comprise variables such as size, organizational structure (i.e. centralized vs. decentralized), formalization, and integration (Grover, 1993). Environmental characteristics include variables such as environmental

uncertainty and heterogeneity as well as competitive intensity, customer power, and vertical coordination (Grover, 1993).

The authors suggest these factors may be important to differing degrees depending on the context or technology. For example, individual factors such as age or education are often more relevant with individual adoption of technology rather than organizational innovation where decisions are often made by committees instead of the individual using the technology. Additionally, task and innovation characteristics of a technology may be isolated and examined when individual technologies are being studied.

In this study, because we are interested in the organizational adoption of a considerable number of supply chain technologies, we will limit our focus to organizational and environmental factors.

2.1.1 Organizational Factors

A variety of organizational factors have been theorized to have an impact on innovation and technology adoption. Size has been one of the most researched variables, which has led to some disagreement of the direction of the relationship. It has been suggested that larger organizations have the financial and technology resources to invest in new technologies and absorb the associated risk (Grover and Goslar, 1993). Furthermore, large organizations may have slack capacity to devote to adopting and implementing new technologies as well as to enjoy the benefits of economies of scale from adoption. Alternatively, others have suggested that smaller organizations are more likely to be innovative because of the flexibility afforded by smaller size and fewer levels

of bureaucracy. Previous research, regardless of the measures used to evaluate size and adoption, has consistently supported the former hypothesis (Rogers, 1990; Dawe, 1994; Premkumar et al., 1997).

Organizational structure has also been considered an important factor to technology adoption (Williams, 1994). Stock et al. (1999) argue that organizational characteristics are closely related to organizational structure. High levels of vertical integration, low flexibility, little information exchange, and low levels of interdependence across firm boundaries typify hierarchical structures. Alternatively, less hierarchical structures or network structures are characterized by high information exchange and high interdependence with outside firms. Facilitating this information exchange and interdependence is advanced information technology (Stank et al., 1999).

Previous research has provided ambiguous results with some studies indicating positive effects of centralization on technology adoption while others have shown negative relationships (Gatignon and Robertson, 1989). Pierce and Delbecq (1977) suggest centralization of decision-making may reduce conflict between organizational units and foster innovation adoption. In support of this proposition, Ettlie et al. (1984) found that organizations with a centralized structure were more likely to adopt new technologies.

However, an alternative approach reasons that organizations that have adopted a flatter, more decentralized structure would be expected to have adopted more innovative and cutting edge technology in order to enhance communication and coordination within the organization as well as with supply chain members (Bowersox and Daugherty, 1995). Grover and Goslar (1993; p.142) suggest that the "decreased autonomy and bounded

perspective" of a centralized organizational structure explain the negative relationship often found between centralization and adoption. Germain et al. (1994) found decentralization (of technology decisions) does not significantly relate to overall technology adoption but may influence decisions regarding integrative technologies. Williams et al. (1998) indicate that a centralized organizational structure is negatively related, although not significantly, to certain dimensions of EDI participation. Grover and Goslar (1993) found decentralization of decision-making was significantly related to usage of telecommunications technologies. Thus, it is expected that a decentralized organizational structure will be associated with the adoption of new technologies.

Past performance is another organizational factor that has been suggested to influence a firm's flexibility (or lack of) and willingness to adjust strategies, to include innovative product or process adoption, in response to changes in the environment (Clemons et al., 1996). Previous research suggests successful and dominant firms often maintain strategies that have worked in the past (Miller and Chen, 1994, Audia et al., 2000). Lant et al. (1992) found firms that had performed better than average in previous years were less likely to initiate a strategic change within two years of the superior performance. Miller and Chen (1994) reached similar conclusions after studying the airline industry. They found a company's previous performance was negatively associated with the number of competitive practice changes. Explanations for this strategic persistence are many. First, organizations are likely to repeat actions that have been successful in the past (Cyert and March, 1963; Prahalad and Bettis, 1986). Successful organizations may have established a corporate culture or a cultural approach to decision making over many years that lead to success. This culture or pattern of

decision-making may inhibit a firm's flexibility to respond to environmental change such as new technologies (Clemons and Hann, 1999). Moreover, dominant firms may have invested heavily in old technologies or information systems that have resulted in large sunk costs, which may become "stranded assets" with little usefulness if new technology were adopted (Clemons and Hann, 1999). In light of theory and previous findings, successful organizations may not be motivated to adopt new supply chain technologies in order to reorganize operations and modify business relationships with buyers and suppliers.

An enduring theme of the strategy literature has been that strategy precedes and directs structure (Chandler, 1962; Egelhoff, 1988). Some authors argue that in order to succeed, organizations must align organizational structure and management processes to changes in the external environment and firm strategy (Galunic and Eisenhardt 1994). The alignment of an integrated supply chain strategy with firm strategy is also becoming vital for firm success (Bowersox and Daugherty, 1995; Gilmour, 1999; Stock et al., 1999). Cavinato (1999) suggests this integration of supply chain strategy with the overall firm strategy has become crucial for achieving and maintaining firm success. As firms realize the increased competitiveness achieved from closer coordination with supply chain partners, management will begin to integrate supply chain management strategies into the firm strategy. This integration should lead to a greater visibility of logistics activities throughout the organization and eventually to the adoption of sophisticated information technology (Bowersox and Daugherty, 1995; LaLonde and Masters, 1994).

2.1.2 Environmental Factors

Numerous innovation studies have examined a variety of environmental factors, including economic conditions, global competitiveness, transaction climate, industry concentration, and environmental uncertainty, on the decision to adopt new technologies (Grover, 1993; Premkumar et al., 1997; Gatignon and Robertson, 1989). In this study, we will focus our attentions on two key variables: interorganizational factors and environmental uncertainty.

Interorganizational Factors

Social exchange theory is a useful framework for examining buyer-supplier relationships (Dwyer et al., 1987). This theory considers relationships between individuals and organizations as an ongoing, dynamic process. Parties interact with one another to exchange valuable resources and continue interacting as long as they perceive the exchange relationship as beneficial. Premkumar and Ramamurthy (1995) claim these interorganizational relationships provide greater control over valuable resources for the participants and potentially reduce uncertainty of the transaction. It has been suggested that these interorganizational arrangements may continue even when not cost effective because of social and political forces that exist between the participants (Pfeffer, 1982). Furthermore, when contingencies arise, the participants may need to adapt their resources to accommodate the other. An example of an adjustment of resources is the adoption of supply chain technology. The willingness of participants to accommodate the needs of

the other partner may be influenced by the state of the relationship or "transaction climate" between partners.

Reve and Stern (1986) emphasize the importance of examining the "transaction climate" within the dyad to fully comprehend interorganizational relationships. The level of trust and cooperation between the firms characterizes the transaction climate. A positive relationship between partners has been found to enhance information exchange, improve interorganizational coordination and cooperation, and result in better decision-making (Williamson, 1975; Dwyer, 1980; Reve and Stern, 1986). Case studies involving American Hospital Supply (Vitale, 1986) and McKesson Drug Company (Clemons and Row, 1988) have illustrated the impact of favorable relationships with customers on interorganizational information system adoption.

Another interorganizational factor that may influence adoption of supply chain technology is competitive pressure from supply chain partners (Premkumar et al., 1997) or from the industry (Norris, 1988). Typically, during the implementation of EDI, one firm initiates adoption and pressures or entices other firms in the supply chain to adopt (Riggins and Mukhopadyay, 1994; Premkumar and Ramamurthy, 1995; Iacovou et al., 1995). Industry associations in the auto and grocery industries have also taken the lead in establishing EDI standards and then coerced organizations to adopt EDI in an effort to enhance communications and improve productivity (Norris, 1988). Research has indicated the initiating firm often obtains more benefits than the follower (Riggins and Mukhopadyay, 1994; Reekers and Smithson, 1994). In spite of this, many firms are forced to adopt or risk losing business. Iacovou et al. (1995) report that more than 70 percent of responders to a series of recent surveys claimed that customer pressure

influenced the firm's decision to adopt EDI. It has been well documented that large retail organizations such as K-mart and Wal-Mart have pressured suppliers to adopt EDI using threats of loss of business (Premkumar et al., 1997).

Environmental Uncertainty

Another recurring environmental factor included in many studies has been environmental uncertainty. Droge and Germain (1998) posit environmental uncertainty may be characterized by unpredictable changes in customer demands, unreliability of supplier quantities and quality, volatile price fluctuations, unpredictable competitor actions, rapid shifts in production processes, and/or brief product life cycles.

Many researchers have viewed environmental uncertainty as a multidimensional concept. Duncan (1972) considers two components of uncertainty: complexity and rate of change. Miller and Friessen (1982) decompose uncertainty into three components: heterogeneity, dynamism, and hostility. Truman (2000) suggests organizations face both external and internal uncertainty. External uncertainty arises from resource and information exchange with the task environment. Internal uncertainty arises from random and unpredictable events occurring between subunits of an organization.

Regardless of the dimensions, the basic idea is "...uncertainty exists because organizations do not have perfect information to make decisions (Walton and Miller, 1995; p.121). In order to overcome imperfect information and uncertainty, organizations tend to institute a variety of mechanisms to "promote, advance, and strengthen coordination" between organizational subunits and partners (Truman, 2000; p. 213) and

innovate in order to survive and flourish (Grover, 1993). Robertson and Gatignon (1989; p.37) suggest demand uncertainty "heightens perceived competitive vulnerability and makes a firm more susceptible to innovation in its quest for competitive advantage." Grover and Goslar (1993) suggest that organizations in relatively stable operating environments do not need innovative information technologies to cope with the information processing requirements. However, when firms face an unpredictable and fluctuating environment, advanced information technology are needed to cope with the uncertainty.

2.1.3 Technology's Impact

The impact of technology has been widely studied with significant contradictions of findings. Several previous research attempts to study the impact of information technology (IT) on performance have resulted in the "productivity paradox". The productivity paradox is the "perceived lack of increased output resulting from investments in information technology" (Sircar et al. p.70, 2000). This term was popularized in the mid 1980s and led to numerous articles that have provided conflicting conclusions. Often, findings have suggested no significant improvement in performance while other studies have shown advantages of IT investment. This concept continues to receive interest from the research community as there were several articles in the *Journal of Management Information Systems* (Spring, 2000) that addressed this topic. Sircar et al. (2000) and Chan (2000) suggest the conflicting results may in part be due to the measures and methodology used by researchers. Many studies focused on the economy or industry

level effects and used measures representing those levels. Some authors used objective measures while others used subjective measures. Some research examined organizational performance while other studies focused on organizational processes. Brynjolfsson (1993; p.67) states, "After reviewing and assessing the research to date, it appears that the shortfall of technology productivity is as much due to deficiencies in our measurement and methodological toolkit as to mismanagement by developers and users of IT." He suggests that many of the studies at that time focused on national level statistics that might not adequately reflect technology effects at the firm level such as improvements in product quality or variety. Additionally, he proposed that benefits from IT require firm restructuring or cost-cutting measures that may not have been implemented. More recent articles appear to suggest positive returns from technology investment when firm level data is used (Brynjolfsson and Hitt, 1996; Dewan and Min, 1997). Dewan and Min (1997) found information technology capital provides excess returns to labor investments and suggests the continued restructuring and downsizing of US corporations should provide measurable economy level benefits as well.

2.2 Supply Chain Management

Supply chain management has been defined by The Global Supply Chain Forum as "...the integration of key business processes from end user through original suppliers that provides products, services, and information that add value for customers and other stakeholders" (Lambert et al., 1998, p.1). A more detailed definition is provided by Simchi-Levi et al. (2000, p.1), who state

> Supply chain management is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and stores, so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time, in order to minimize systemwide costs while satisfying service level requirements.

In the past, managers attempted to optimize their individual segment of the logistics process. This narrow-focused approach to logistics management, or the "functional silo" approach, occurs when managers attempt to optimize their own logistics function to the possible and likely detriment of the overall logistics process (Taylor, 1999). However, with implementation of supply chain management, the narrow focus of managers and the adversarial relationships between logistics providers, suppliers, and customers is replaced with strategic alliances and long-term cooperative relationships and viewing suppliers and customers as partners instead of adversaries (Tan et al., 1998) with the objective of "maximiz(ing) competitiveness and profitability for the company as well as the whole supply chain network including the end-customer" (Lambert et al. 1998, p. 4).

Integrating logistics activities within and between firm boundaries may lead to a variety of operational improvements. Levary (2000, p. 25-26) suggests supply chain integration may have several beneficial effects including:

1. Minimizing the bullwhip effect
2. Maximizing the efficiency of conducting activities along the supply chain
3. Minimizing inventories along the supply chain
4. Minimizing cycle times along the supply chain
5. Achieving an acceptable level of quality along the supply chain

The bullwhip effect, or demand amplification, occurs when variations in demand are amplified as distorted information is passed along echelons in the supply chain.

These distortions often lead to unnecessary inventory investment, capacity planning difficulties, production planning problems, inefficient use of transportation, lost revenue, and poor customer service (Lee et al. 1997). Better information exchange between supply chain partners, perhaps the key advantage of an integrated supply chain (Lee et al, 1997; Levary, 2000), can diminish the bullwhip effect (Taylor, 1999). Up-to-date information allows more accurate inventory responses to changes in demand and thus more appropriate inventory levels throughout the supply chain (Levary, 2000, Stank et al., 1999). Another advantage of integration includes capturing synergies within and across businesses while avoiding the cost of vertical integration. Synergies result from "…shared expertise and resources, exchange of information, mutual planning and support, and joint problem solving fostered by win/win, mutually committed trading partners" (Stank et al. 1999, p. 25).

Zuckerman (2000) claims effective integration of logistics activities may reduce inventory transit times, manufacturing cycle times and thus overall inventory levels. Previous trade journal surveys indicate the integration of the supply chain has had significant impact on some firms. Quinn (1998) reports the results of a study that suggest that companies with "best practice" logistical processes experience a 45 percent reduction in supply chain cost compared to their competitors. Additionally, these companies with distinctive logistic capabilities maintained 50 percent less inventory days and had an order-cycle time of half than that of their competitors. Another study revealed that supply chain inefficiencies can increase operating costs by as much 25 percent. Cross (2000) suggests large companies often experience a 10 to 80 percent improvement in supply

chain functions and a 10-50 percent cost improvement after implementing effective supply chain management practices.

The impact of supply chain management has also been widely reported in academic journals. Armistead and Mapes (1993) studied manager's perceptions and found closer relationships with customers and greater information exchange correlated positively with improvements in manufacturing performance. Separate studies by Monczka, et al. (1998) and Vonderembse and Tracey (1999) found that close buyer/supplier relationships lead to improvements in quality, cycle time and new product development as well as on-time delivery, reduced damage and parts quality. Stank et al (1999) found a significant relationship between supply chain coordination and three performance criteria: decreased inventory levels, decreased order cycle time, and decreased order cycle variance. Stank and Lackey (1997) found capabilities involving integration (i.e. functional integration and information sharing) were particularly important to overall logistical performance. Maquiladora firms that integrate logistics functions internally as well as between the firm and other echelons of the supply chain performed better and experienced improvements in order cycle time, increases in on-time delivery, and decreased expedited shipments. Supply chain management practices have also been shown to impact corporate performance. Sharing confidential information and using integrated teams to set goals was shown to correlate positively with financial and market performance (Tan et al., 1998)

Other studies have examined factors leading to effective integration of supply chain partners. Tan et al. (1998) suggest certain organizational conditions must first be in place. Organizations must focus on optimizing the entire supply chain instead of

concentrating on their particular link in the chain. However, firms profit from information asymmetry and may not wish to allow supply chain members access to their proprietary information. Additionally, information asymmetry provides bargaining power to those firms with the information. Firms may not wish to forego bargaining power in order to maximize efficiency throughout the supply chain.

To forego the information asymmetry of the old supply chain paradigm, Stank et al. (1999) suggest trust and open communication must replace secrecy and exploitation of supply chain members. Whipple and Frankel (2000) found that buyers and suppliers agree that trust is one of the five most important success factors in strategic alliances. Bowersox et al. (2000; p.10) claim, "Effective information sharing is heavily dependent on trust beginning within the firm and ultimately extending to supply chain partners." Trust leads to more effective information sharing which results in less uncertainty throughout the supply chain. Firms are thus able to quickly respond to changes in customer demand and adjust inventory levels and avoid the demand amplification that is common in traditional logistics settings. Thus, trust and information sharing must be incorporated into the culture of organizations participating in an integrated supply chain. Numerous researchers have concluded that frequent and trustworthy communications influences performance (Zaheer et al. 1998a) and can even substitute for inventory (Stank et al., 1999).

Advanced information technologies are also vital to establishing communications between organizations and effectively managing an integrated supply chain (Stank, et al. 1999). Better exchange of information is the key ingredient to effective supply chain management (Lee et al, 1997; Levary, 2000) and technology provides the capabilities to

transfer more accurate and up-to-date information resulting in better visibility of demand and products throughout the supply chain. As mentioned earlier, thirty-four percent of logistics executives rank technology as the most important factor in improving logistics capabilities (Bradley et al. 1999). A variety of information technologies are available to enhance inter- and intra-firm cooperation, such as bar codes that increase information and material flows, information networking capabilities that improve communication and coordination between firms, computer aided design that enhances design coordination, transportation management systems that improve communication with the transportation industry and enterprise resource planning systems as well as supply chain planning systems that attempt to integrate information systems (Johnston and Lawrence, 1988).

2.3 Transaction Cost Economics and Technology

Transaction cost economics provides a useful perspective for examining technology adoption within a supply chain context. Introduced by Coase (1937), transaction cost economics (TCE) has historically been used as a framework to explain the scale and scope of the firm. According to this theory, firms consider production and transaction costs to determine the lowest total cost in deciding governance structures and mechanisms (Williamson, 1991). More recently TCE has been used to analyze a range of business relationships including vertical and lateral integration of firms, multinational corporations and strategic alliances (Ghoshal and Moran, 1996). The TCE perspective has also been useful for examining supply chain relationships (Clemons and Row, 1992;

Clemons et al., 1993; Premkumar, 2000) as well as providing a sound theoretical basis for interorganizational information system adoption (Clemons and Row, 1992).

Market transactions may be favored when production economies of scale or scope allow specialized firms to produce at a lower cost. However, when transaction uncertainty exists, hierarchical organization may be preferred. According to Williamson (1975), bounded rationality is one of the most important obstacle to market transactions. Individuals are limited in cognitive capacity and cannot identify and comprehend *ex ante* all possible scenarios. Thus, transactions are often internalized to allow for adaptation in the future instead of attempting to anticipate all possible futures (Williamson, 1975).

Among other factors, asset specificity and opportunism also influence the type of transaction. Asset specificity refers to assets that are predominantly useful to a particular business relationship. As asset specificity increases, internalization of the transaction is likely because of the greater oversight provided by firm governance structures. Williamson (1993, p.102) defines opportunism as "self-interest seeking with guile" and suggests individuals will act in a "calculated effort to mislead, distort, disguise, obfuscate or otherwise confuse" (Williamson, 1985, p.47). The potential for opportunistic behavior creates uncertainty in the transaction process and increases the likelihood of hierarchical organization. As Zaheer et al (1998b; p.144) state, "...bounded rationality, uncertainty, and information asymmetries stemming from imperfect communication, private information, and observation and verification difficulties, all contribute to increasing costs of negotiation."

Information technology has the potential for controlling several aspects of transaction costs by improving coordination and cooperation between supply chain

members (Clemons and Row, 1992; Clemons et al., 1993; Premkumar, 2000). According to Clemons and Row (1993), coordination difficulties arise from uncertainty due to lack of accurate and up-to-date information or limited information processing capacity. Thus, improving the timeliness, quality and amount of information transmitted between firms can reduce uncertainty and enhance coordination. Information technology more effectively and efficiently processes (i.e. moving, verifying and formatting) information (Clemons and Row, 1992) and thus potentially enhances inter-firm coordination.

Information sharing technologies also reduce transaction costs by reducing the cost of exchanging information and by managing risk (Clemons and Row, 1992; Bakos and Brynjolfsson, 1993). For example, Sutton (1997) reports that electronic communications reduce purchase order costs from \$50 to \$5. Better management of uncertainty is provided by information technology by providing better monitoring of supplier performance through more efficient database management and processing of data (Clemons and Row, 1992).

2.4 Technology and The Supply Chain

In addition to enhancing communication flows, information systems may influence firm size, business procedures, buyer - supplier relationships, and firm bargaining power (Bowersox and Daugherty, 1995; Lewis and Talalayevsky, 1997; Williams et al. 1997; Clemons and Row, 1991). Bowersox and Daugherty (1995) suggest information technology is a critical factor in four major logistics trends as well:

1. More decentralized logistics organization structures
2. More boundary spanning relationships
3. A more focused approach to performance measurement
4. A greater focus on time-based strategies

Much of the early research examining technology adoption in the logistics literature focused on organizational variables. Bowersox et al., (1989) were some of the first to explore factors leading to technology adoption in logistics settings. They found that firms with a superior logistics management competency were more likely to have adopted information technologies. Rogers (1990) found two variables associated with technology adoption in logistics: (1) the size of the firm as measured by annual sales and (2) the presence of a formal logistics mission statement and strategic plan. Dawe (1994) found information technology use for logistics activities was related to firm size, the use of complex performance evaluation, and the presence of a department called "logistics". Germain et al. (1994) found a variety of organizational variables relate differently to technology adoption depending on the type, cost, and impact of the technology. Size of the firm was positively related to all types of technology while organizational age, decentralization and number of organizational layers was not significantly associated with technology adoption.

More recently, the literature has focused primarily on the adoption of proprietary Electronic Data Interchange (EDI); the most common form of interorganizational information systems. EDI refers to a proprietary computer-to-computer exchange system enabling the transfer of high-volume, routine business information between trading partners, using a national or international standard format (Sawabini, 2001). Initial EDI studies were simply descriptive and reported the extent of firm usage of EDI (Lieb and

Miller, 1988; La Londe and Cooper, 1989; Crum and Allen, 1990). Later studies began focusing on important variables influencing EDI adoption. Williams (1994) examined the influence of several factors, including internal organizational factors, environmental factors, and interorganizational dimensions on EDI adoption in both the marketing and logistics channels. She concluded that organizational size and demand uncertainty were significant factors motivating suppliers and customers in the marketing channel, and channel power was important in the logistics channel. In a later study using a variety of measures of EDI participation, Williams et al. (1998) found that EDI investment, length of EDI use and partner selectively were all positively related to EDI participation. They concluded that technological uncertainty and organizational structure are not related to EDI participation. Their results also suggest that a centralized organizational structure is negatively related, although not significantly, to some dimensions of EDI participation.

The organizational benefits of interorganizational information systems have also been extensively examined. Previous research indicates interorganizational information system (of which EDI is the primary example) adoption has lead to reduced costs of order processing (Sutton, 1997), reduced order lead-time and higher service levels (Stern and Kaufmann, 1985), increased accuracy and efficiency (Allen et al., 1992; Walton and Marucheck, 1997) and lower inventories and decreased order cycle time (Stank et al., 1999).

3. CONCEPTUAL FRAMEWORK AND HYPOTHESES

The examination of the relevant literature above suggests the importance of a more thorough understanding of the factors leading to technology adoption and the resulting benefits in a supply chain context. This chapter presents a graphical model and corresponding hypotheses focusing on the key organizational and environmental variables and benefits of supply chain technology adoption and implementation.

The model in Figure 1 represents the environmental and organizational variables examined and the nature of their relationship with supply chain technology adoption as well as the potential benefits. Justification for each research hypothesis is included below.

3.1 Hypotheses

Antecedents

Previous research has consistently indicated organizational size positively correlates with technology adoption (Dewar and Dutton, 1986; Rogers, 1990; Dawe, 1994; Germain, 1993; Germain et al., 1994). Studies examining individual technologies such as EDI, (Daugherty et al., 1995; McGowan and Madey, (1998); Premkumar et al., 1997) also found firm size to be an important factor to the adoption process. Larger organizations are expected to possess the financial resources needed for new technology investments as well as the capacity to bear the risks associated with innovation (Grover

and Goslar, 1993). Furthermore, Cragg and King (1993) showed that lack of the technical knowledge and resources inhibit technology adoption in small firms.

H1: The larger the organization, the more likely it will be to adopt supply chain technology.

Organizational structure is another factor that has been widely studied with conflicting results found. Williams (1994), as well as Gatignon and Robertson (1989), proposed that a centralized organizational structure facilitates decisions requiring organizational standardization and thus would be more likely to be associated with technology adoption. Successful information technology utilization within and between organizations would require considerable standardization throughout the firm. Conversely, centralization, or concentration of decision-making has been argued to be negatively associated with adoption and implementation. Centralization is believed to lead to reduced environmental scanning and thus a more bounded perspective, which would lessen the awareness and understanding of potential innovations (Grover and Goslar, 1993). These authors found that decentralized decision-making is positively related to usage of telecommunications technology. Germain et al. (1994) found a weak relationship between decentralization and adoption decisions regarding integrative technologies, while Williams et al. (1998) results suggest a similarly statistically insignificant negative relationship between a centralized organizational structure and certain dimensions of EDI participation.

H2: The more decentralized the organization, the more likely it will be to adopt supply chain technology.

Clemons and Row (1991) suggest information systems have become essential components of firm strategy. Executives realize new information systems have the potential to fundamentally affect business procedures, operational routines, buyer-supplier relationships and bargaining power. Thus, adoption of a host of new supply chain technologies is likely to accompany a change in organizational strategy.

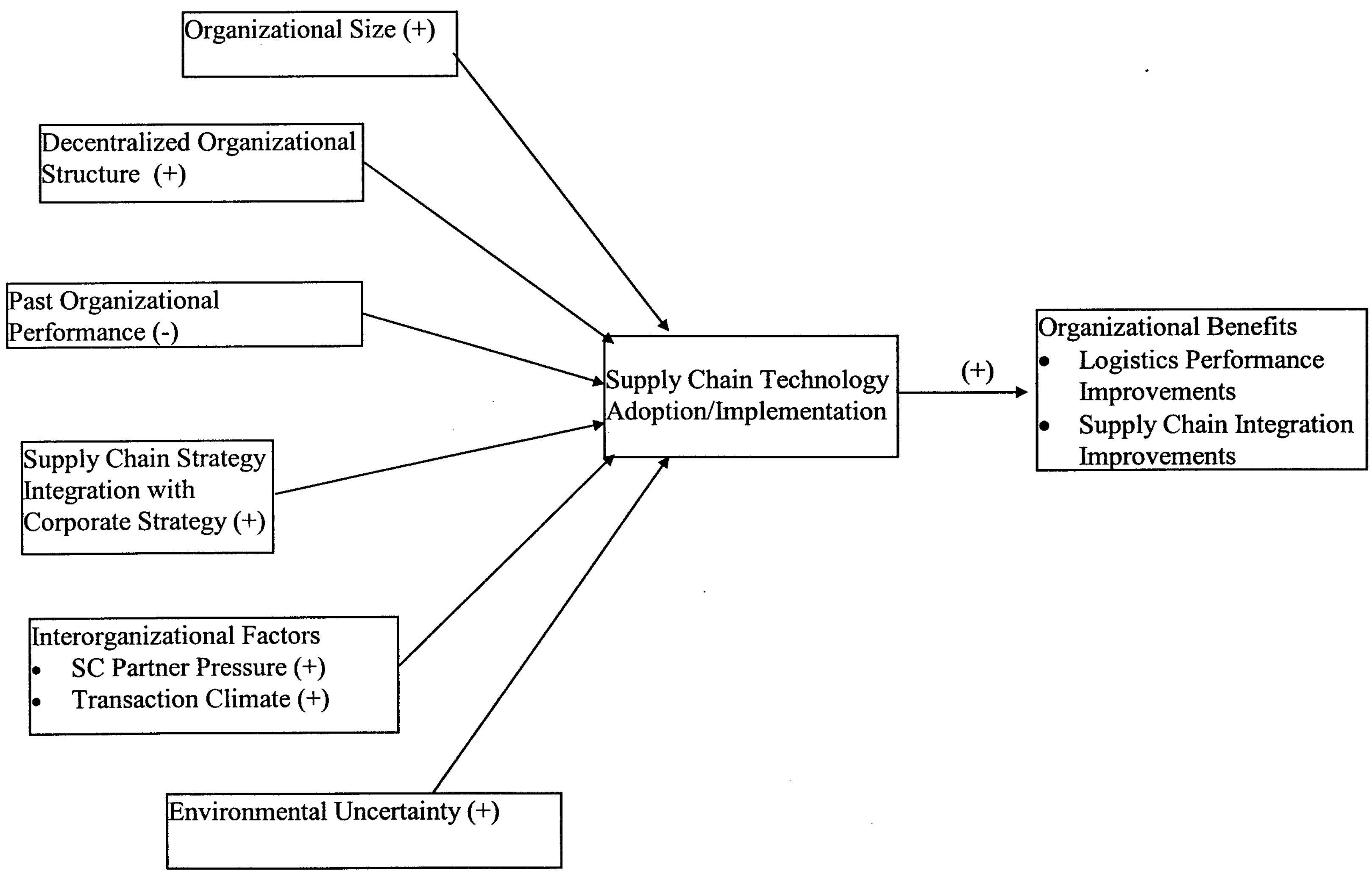
Strategic management literature provides meaningful insight of the impact of past performance on strategic change. Grimm et al. (1993), studying the transportation industry, reported that past performance had no effect on the likelihood of strategy changes. However, in a follow-up study, Feitler, Corsi and Grimm (1998) found greater strategic change in poorer performing firms than in better performing firms. Other authors (Zajac and Kraatz, 1993; Audia et al., 2000) also report that successful past performance tends to lead to resistance in strategic changes. Clemons and Hann (1999, p.9 and 19) note that "success all too often sows the seeds for future failure" because managers of many successful organizations "find it exceedingly difficult to change their business strategy radically in response to impending changes in their competitive environment". Many reasons have been provided to explain the reluctance of successful firms (Clemons and Hann, 1999). Successful firms may develop a set of beliefs and behaviors that they use to explain firm success and use these beliefs when making decisions even though changes in the environment may have rendered these beliefs and decision processes inappropriate. Secondly, successful firms may be committed to

investments in resources that may be rendered useless after a strategic change. Finally, managers of successful firms may resist change if it may affect their value or position in the firm. Audia et al. (2000) found that firms in the airline and trucking industries were more likely to continue with a strategy once success had been achieved. Thus, successful firms will be less likely to adopt new supply chain technologies and implement strategy changes.

H3: Less successful organizations in the past will be more likely to adopt supply chain technology.

Logistics and supply chain integration is beginning to be seen as a strategic resource with the potential of providing competitive advantage (Lewis and Talalayevsky, 1997; Olavarrieta and Ellinger, 1997). As firms realize the efficiencies gained from improved logistics, management begins to focus on logistics strategy and incorporate it into overall firm strategy (Bowersox and Daugherty, 1995). The realization of increased competitiveness from supply chain integration and the resulting inclusion into overall firm strategy should lead to strategic alliances among members of the supply chain and eventually to technological integration. Thus, firms that have integrated supply chain management with firm strategy will be more likely to have assumed supply chain management practices and to have adopted innovative information systems.

Figure 1. Antecedents and Benefits of Technology Adoption



H4: Organizations that have integrated supply chain management strategy with overall corporate strategy will be more likely to adopt supply chain technology.

Much of the research examining the impact of trading partners on technology adoption has focused on EDI adoption (Premkumar and Ramamurthy, 1995; Truman, 2000). Iacovou et al. (1995) found small organizations utilizing EDI have often had the technology imposed on them by larger trading partners. Dominant partners or "technology champions" may pressure members of the chain to adopt supply chain technologies in order to standardize data formats and improve coordination and communication within and between organizations of the supply chain. Truman (2000) explains that "sponsor" organizations may take the lead in a supply chain to develop and operate an EDI system and coerce other members to adopt the technology as well. Bouchard (1993, p. 366) concludes an organization's decision to adopt EDI "is primarily based on what [its] business partners are doing and not on the characteristics of EDI." For similar reasons, other supply chain technologies that standardize data formats and enhance information sharing may be adopted by organizations because of the influence of partners in the chain in order to streamline transactions and improve inter-firm communication.

H5: Organizations subjected to greater supply chain partner pressure will be more likely to adopt supply chain technology.

Social exchange theory asserts that relationships and social factors between organizations influence firm activities and transactions in addition to market factors

(Premkumar and Ramamurthy, 1995). The "transaction climate" represents these relationships and social elements between organizations. Trust and faith between firms are key elements of the transaction climate and are expected to be important factors in the adoption of supply chain technology. A high level of trust and commitment between firms adopting supply chain technology may be required because the automation of transactions eliminates manual oversight systems and the paper documentation that exist to ensure accurate and reliable transactions (Premkumar and Ramamurthy, 1995). Walton and Miller (1995) suggest previous history of the business relationship, an indicator of the trust and respect between partners and thus transaction climate, impacts EDI adoption. Enduring and trusting relationships between organizations have been shown to be a key motive in electronic integration (Konsynski and McFarlan, 1990). Furthermore, Nidumolu (1995), studying the insurance industry, found that investments in interorganizational information systems are associated with a positive transaction climate. Thus, relationships between organizations characterized by trust and cooperation are expected to be positively related to supply chain technology adoption.

H6: Organizations with a more favorable transaction climate with supply chain members will be more likely to adopt supply chain technology.

Ahmad and Schroder (2001) argue an uncertain environment requires the frequent exchange of information among business partners so that activities can be prioritized as changes occur. The greater the uncertainty, the more difficult it is to meet delivery expectations and the greater the need for more information exchange.

Uncertainty in today's hyper-competitive marketplace compresses the decision-making time frame and thus increases the need for faster, more accurate information. Advanced information technologies integrated within and between members of the supply chain allow firms to more quickly and accurately share demand data, sales projections and production schedules which provides greater real time inventory and demand visibility (Kwan, 1999). Previous research showed that higher levels of uncertainty related positively with a greater need for changing technology and faster adoption rates (Ettlie, 1983). Demand uncertainty has also been found to be related to technology adoption (Robertson and Gatignon, 1986). Thus, firms facing above average environmental uncertainty will have a greater incentive to adopt supply chain technology to improve information exchange and manage uncertainty between organizations and their task environment.

H7: Organizations facing higher environmental uncertainty will be more likely to adopt supply chain technology.

Organizational Benefits

Numerous studies have examined the first level effects of interorganizational information systems (IOSs) on logistics performance. Results suggest IOSs reduce inventory levels (Mukhopadhyay et al. 1995), reduce costs (Sutton, 1997), reduce cycle times (Sutton, 1997, Stank et al., 1999), result in fewer stockouts, and improve ordering and shipping accuracy (Stern and Kaufmann, 1985). Stank et al. (1999) submit sharing knowledge and exchanging critical information with trading partners can enhance

operating performance and support business relationships. They found that information technology improved supply chain coordination and led to decreased inventory levels, decreased order cycle time and decreased order cycle variance. In another study, information technology was found to significantly reduce order cycle time and improve routing and scheduling of inbound shipments (Stank and Lackey, 1997). However, Rabinovich et al. (2002) found enterprise-wide information systems do not lead to improved inventory performance and may actually worsen inventory turnover rates. Nonetheless, it is expected that adoption and implementation of a wide range of supply chain technologies will enrich information exchange within and between organizations resulting in improved supply chain performance as measured by inventory levels, logistics costs, shipping accuracy, cycle times and customer service.

H8: Adopting organizations will be more likely to have achieved higher levels of logistics performance improvements.

A variety of factors have been suggested to be critical to the effective integration of supply chain partners. Some of these factors include trust between partners (Stank, et al., 1999; Moore and Cunningham, 1998; Zaheer et al., 1998a; Whipple and Frankel, 2000), commitment between partners (Moore and Cunningham, 1998), information sharing (Stank, et al., 1999; Stank and Lackey, 1997; Whipple and Frankel, 2000), and logistics coordination (Stank and Lackey, 1997; Kohn and McGinnis, 1997).

Information technology has the potential to impact organizational integration by facilitating information exchange and coordination of activities (Clemons and Row, 1992). Information processing activities ("moving, verifying, formatting, or

synthesizing" information) can be accomplished more efficiently and accurately using information technology. Consequently, information technology is expected to enrich information sharing (Clemons and Row, 1992; Stank et al. 1999) by enabling analysis and management of larger databases and generation of more complete information, which leads to quicker and more accurate exchange of information. Stank et al. (1999) suggests information technology has the potential to expand an organization's information processing capacity and improve coordination. Daugherty, et al. (1995) suggests one of the key advantages of electronic integration is the speed and ease of exchanging information with partners; thereby enhancing coordination.

There has been little research on the effects of technology on supply chain integration. Initial results indicate inter-firm coordination improves when information technology replaces personal coordination (Kekre and Mukhopadhyah, 1992). However, Kraut et al. (1998) found electronic integration was negatively associated with order quality, efficiency, and satisfaction with suppliers. In light of the strong theoretical support and limited conflicting empirical evidence, we propose supply chain technology adoption should lead to improved integration between firms as measured by information sharing and coordination of logistics activities

H9: Adopting organizations will be more likely to have achieved higher levels of supply chain integration improvements.

4. RESEARCH METHODOLGY/DATA

The purpose of this section is to present and discuss the research methodology and data utilized in this study. The chapter is organized into the following sections: survey development, survey items, content validity, respondents, and data analysis.

4.1 Survey Development

To test the research model, a survey instrument was developed in collaboration with supply chain consultants from the Revere Group, a business-consulting firm that assists mid-market and larger companies utilize technology to improve operations. The survey consisted of a series of five-point Likert scaled questions typically anchored with "Not at all" and "To a great extent" as well as several open-ended questions (See Appendix for complete survey).

The Revere Group consultants and their clients developed the list of supply chain technologies included in the survey. The list includes a variety of technologies ranging from mature and widely used technologies such as bar coding technology to relatively new software applications such as supply chain planning systems and supply chain event management systems. The one theme that runs through all of these technologies however is that all are primarily concerned with managing and controlling supply chain related data and activities and information exchange within and between organizations.

Automation technologies such as robotics and material handling equipment were not be addressed in this study.

4.2 Scale Items

Several scale items were used to measure concepts related to organizational structure, organizational size, environmental uncertainty, supply chain strategy integration, supply chain pressure, transaction climate, organizational performance, technology adoption/implementation, supply chain integration and logistics performance. Multiple scale items, though not intended to be duplicative, were included in the survey to provide an array of evaluation alternatives. Unless questions were reverse coded, higher values indicate a greater level of the construct under investigation.

Organizational size was measured in terms of total number of employees and total revenue. The median value of the range of values on the survey were used as the measure of organizational size. For the fifth choice, 5001 or more employees and more than $2 billion in revenue, actual values for seven of the firms responding with this choice were determined. The average number of employees and revenues for these seven firms, equaling 35,300 employees and $11.5 billion, was then used in the analysis. Both measurements have been used to represent organizational size and both were collected to provide a richer evaluation of its impact on supply chain technology adoption.

Organizational past performance was determined using questions 4c) 4d) and 4e) which focused on average annual market share growth, average annual sales growth and average annual growth in return on total assets over the previous three years. The

respondents were asked to rate their firm's performance in comparison with major industry competitors on a scale of 1 to 5 with anchorings of "Well Below Average" to "Well Above Average." These questions allow us to examine perceptions of previous performance using a variety of measures to obtain a more complete perspective of organizational performance and its impact on supply chain technology adoption. Including a three-year time frame allows us to examine past performance as well reduce the possibility that an extremely profitable or unprofitable year might confound the data analysis.

Organizational structure was explored using questions 1a) (Williams, et al. 1998) 1c) and 1d). Question 1a) was reverse coded so that lower values indicate a more decentralized organizational structure. For questions 1c) and 1d), higher values represent greater levels of decentralization. These questions focus on decision-making, cross-functional teams and integration of operations to ascertain a firm's organizational structure.

Supply chain management strategy incorporation was examined using questions 1b), 1e) and 1f) (Kohn and McGinnis, 1997). These questions attempt to gain a better understanding of the degree to which the organization have incorporated supply chain management strategy into their overall organizational strategy. Higher values suggest greater incorporation of supply chain management strategy.

Environmental uncertainty was measured using questions 5c), 5d), 5e) (Klass et al., 1999). Question 5c) was reverse coded. These questions inquire as to the amount of uncertainty in demand as well as the change and uncertainty faced by the company and its industry.

Interorganizational factors represent (1) the pressure imposed by supply chain partners to adopt technology and (2) the transaction climate between the responding firm and its supply chain members. Questions 11f), 11n), 11u), and 11dd) were used to ascertain the degree to which partners of the responding firm's supply chain had encouraged the firm to adopt supply chain technology. Questions 11a), 11b), 11i), 11j), 11q), 11r), 11y), and 11z) represent the transaction climate by addressing the commitment and trust between the responding firm and its supply chain members.

Question 12 provides a list of thirteen functional technologies and asks the respondent the degree of adoption and implementation on a scale from 1 to 5. Question 16 examines the adoption and implementation of two key integrating information systems: enterprise resource planning system (ERP) and supply chain planning system (SCP). This approach allows for an examination of the degree of adoption of each individual technology as well as an overall measure of supply chain technology adoption by averaging the responses across all technologies.

The concept of "adoption" has been defined in a variety of ways. For example, authors have distinguished between adoption, diffusion, initiation, development, implementation and use. While recognizing these legitimate distinctions, for this exploratory study, we have chosen to use "adoption" in the broadest sense so that it encompasses "the generation, development, and implementation..." of the technologies (Damanpour, 1991; p.556). Furthermore, it is our belief that supply chain managers probably do not distinguish between stages of the adoption process and attempting to clearly tease out these distinctions on our survey would result in an unwieldy and complex set of survey questions that may confuse respondents.

Organizational benefits of supply chain technology adoption were categorized as benefits to logistics performance as well as to supply chain integration. Logistics performance was measured by questions 21a) -21m), which included benefits gained in such areas as: inventory levels, logistics costs, shipping accuracy, cycle times, customer service, customer satisfaction, and delivery . Questions 21n) and 21o) address the impact of supply chain technology adoption on the integration of the supply chain members by focusing on the improvements to information sharing and coordination. Questions 21p) and 21q) explores the increases in trust and commitment resulting from supply chain technology adoption. The impact of supply chain technology and E-commerce on the performance of the entire supply chain was addressed with question 22.

Because of the difficulty in objectively measuring logistics performance (See Chow et al. 1994 for a review) and therefore the logistics benefits of supply chain technology, executive perceptions have been used instead. Admittedly, there are concerns as to the suitability of using executive perceptions for two reasons (Tallon et al., 2000). First, as with any self reported data, the possibility exists that executives will bias their responses either consciously or unconsciously as a means of self-promotion. Second, because of the size and complexity of modern organizations, managers or executives may not have an adequate or accurate understanding of the impact of information technology on the organization. However, previous research suggests that senior executives are an appropriate source of information concerning information technology and benefits (Tallon et al., 2000). Venkatraman and Ramanujam (1987; p.18) found a high degree of correlation between senior manager perceptions of performance and objective performance measures such as sales growth, net income growth and ROI

and concluded that "perceptual data from senior managers...can be employed as acceptable operationalizations of [business economic performance]". Furthermore, DeLone and McLean (1992) suggest that senior executives are capable of determining the impact of IT on their firm because of their key position within the firm provides the knowledge of technology's impact on their organization. Additionally, as information technology becomes a key aspect of organizational strategy, executives are becoming more involved with technology adoption issues and attentive to subordinates familiar with the organizational effects of technology investment (Tallon et al., 2000). Thus, researchers have concluded that executives are a reliable source for examining the impact of technology on organizational performance.

4.3 Content Validity

Validity refers to the accuracy of a measure and addresses the degree to which an indicator accurately measures the intended construct (Garver and Mentzer, 1999). Construct validity is often measured using three approaches: content, convergent, and discriminant validity. Content validity, or face validity, subjectively evaluates the concordance between scale items and constructs. There is no rigorous assessment of content validity but is established when identifying items to be used in the survey and through the process of pre-testing and pilot testing.

In this study, content validity was established by using scale items from previously validated surveys and through extensive testing with academicians, business consultants and supply chain managers. The initial survey was presented to a group of

four logistics academicians and consultants. Items were evaluated for clarity, completeness, relevance, and flow. After several modifications, the survey was pre-tested on a group of almost 50 Revere clients. The respondents provided valuable feedback that led us to further refine the survey by deleting and rearranging several sections and slightly modifying several questions to improve readability and understanding. Although subjective, the extensive use of previously used scale items and extensive pre-testing suggests adequate support for content validity of the scale items.

Two other forms of validity - convergent and discriminant - refer to the degree to which multiple measures of the same construct relate and the degree to which similar concepts are different, respectively (Hair et al., 1998). These forms of validity are not considered in this study as most of the constructs are represented by single scale items. The two concepts represented by multiple scale items, supply chain partner pressure and transaction climate, are composites of scale items that represent environmental conditions. However, the individual scale items are not intended to represent the same construct, but are combined to provide a more complete and global picture of the environmental conditions.

4.4 Respondents

The survey was initially mailed in November 2001 to 1554 high level managers contained in the Revere Group database. The survey was placed on the World Wide Web in February 2002 and emails were sent to 378 of the managers in the Revere database with email addresses informing them of the online survey and requesting participation.

At the same time, emails were sent to 1873 managers contained in the Council of Logistics Management database to improve sample size and increase variability. A third database, provided by Logistar, a company that organizes and conducts logistics seminars, contained 3000 names and was utilized as well. Two hundred eighty five surveys were undeliverable by mail or email resulting in an effective sample size of 6142. A total of 107 useable surveys were received.

The response rate of almost 2% may have been due to a variety of reasons. First, the initial survey was mailed shortly after the attacks of September 11 and the anthrax attacks using the US Postal Service. Thus, mail throughout the US was not being delivered as usual and individuals were hesitant to open mail from unknown sources. A second explanation for the low response rate was provided by several recipients of the email. Several responded that due to the slowdown in the economy, many employees had been released from work and the company no longer had the manpower to respond to surveys. Finally, the detailed nature and length of the survey may have deterred some potential respondents.

Though the response rate may be considered comparatively low, the wide range of companies represented, with respect to both industry and size (Tables 1 and 1a), provides a valuable database for the exploratory study. The group of respondents consisted of 107 firms primarily located in the US. Almost 47% of the respondents represented manufacturing firms while 24% of the respondents were logistics service providers. Roughly 10% of the firms participated in other service industries such as financial and health care service providers. The significant array of firms represented in the group of respondents compels careful consideration as firms from different industries or echelons

of the supply chain may require distinct types of technologies. For example, service providers catering to consumers, may require different technologies from manufacturers who are located more upstream with suppliers and distributors as partners. In addition to different technological requirements, distinct environmental and organizational factors may impact the decision to adopt supply chain technologies.

In an effort to address these concerns, the data was analyzed in three separate groupings. First, the complete data set of 107 respondents was analyzed to report overall results. The second group of respondents analyzed were the 50 manufacturers. The final group consisted of the 26 logistics service providers. These subsets of the sample enable a comparison and contrast of the technologies adopted, the functional areas, and benefits achieved by firms in the various industries.

Firm size was measured in terms of annual revenue, employee number, and geographic scope (Table 1a). Both large and small firms were well represented in the survey sample, although large companies appear to be over represented in the group of respondents. The small number of respondents in the middle category (representing revenues between $500 million and $1 billion as well as employees of between 501-1000) may simply be a function of the size of range. Roughly one fourth of the responding firms had national operations while more than half of the respondents had operations encompassing the world.

4.5 Data Analysis

The comprehensive nature of the survey provided a wide variety of analysis options. First, the current state of supply chain technology employment was investigated and reported. The next step was to examine the correlations between the independent variables and two measures of supply chain technology adoption: extent of technologies adopted and degree of functional area adoption. The third stage of analysis involved regression analysis to test the first seven research hypotheses by assessing the impact of the seven organizational and environmental factors on supply chain technology adoption. The final analysis conducted was correlation analysis between technology adoption and benefits achieved by the firms to test Hypotheses 8 and 9.

Table 1: Descriptive Statistics

Industry	# of Respondents	% of Respondents
Manufacturers		
Food and Kindred Products	15	14
Tobacco Products	1	0.9
Lumber and Wood Products	1	0.9
Furniture and Fixtures	1	0.9
Printing and Publishing	1	0.9
Chemicals	2	1.9
Rubber and Miscellaneous Plastics	3	2.8
Stone, Clay, Glass, and Concrete products	4	3.7
Primary Metal Products	1	0.9
Fabricated Metal Products, Except Machinery and Trans. Equipment	2	1.9
Industrial and Commercial Machinery and Computer Equipment	11	10.3
Electronic and Other Electrical Equipment	6	5.6
Measuring, Analyzing, and Controlling Instruments	1	0.9
Transportation Equipment	1	0.9
Financial Services	3	2.8
Healthcare Services	2	1.9
Retail	7	6.5
Ministry	1	0.9
Logistics Services	26	24.3
Marketing Services/Products	2	1.9
Distributor	9	8.4
Utility Services	1	0.9
Education	1	0.9
Restaurant	1	0.9
Unreported	4	3.7
Totals	107	100.00%

Echelon Groups	# of Respondents	% of Respondents
Manufacturers	50	46.7
Distributors	9	8.4
Retailers	7	6.5
Logistics Service Providers	26	24.3
Other Service Providers	11	10.3
Unreported	4	3.7
Totals	107	100.0%

Table 1a: Descriptive Statistics Continued

	# of Respondents	% of Respondents
Annual Revenue		
$100 million or less	24	24
MORE than $100 million, to $500 million	31	31
MORE than $500 million, to $1 billion	7	7
MORE than $1 billion, to $2 billion	13	13
MORE than $2 billion	26	26
	101 total responses	
Number of Employees		
100 or Fewer	13	13
101 - 500	18	17
501 - 1000	7	7
1001 - 5000	32	31
5001 or More	34	33
	104 total responses	
Geographic Scope		
Regional	12	12
National	29	28
Worldwide	61	60
	102 total responses	

5. RESULTS AND DISCUSSION

5.1 State of Supply Chain Technology Employment

Technology and related applications continue to evolve at a seemingly ever-increasing pace. The rapid rate of change may have rendered past examinations of logistics technology adoption outdated and irrelevant. Thus, it is important to understand the current state of supply chain technology employment, the factors influencing adoption, and the benefits achieved.

This chapter addresses those issues by first providing an analysis and discussion of the extent of adoption of the 15 key supply chain technologies included in the study. The results of correlation analysis between the independent variables and technology adoption measures are then described. The final section presents the results of regression and correlation analysis used to test the nine hypothesized relationships included in the research model (Figure 1).

5.1.1 Technology Adoption

The initial objective of this research was to characterize the current state of supply chain technology employment. The 15 technologies examined in this study were grouped into two categories: functional technologies and integrative technologies. Functional technologies include systems that are used to accomplish a particular function or used in a particular functional area such as Warehouse Management Systems and Transportation

Management Systems. Examples of integrative technologies include Enterprise Resource Planning Systems (ERP) and Supply Chain Planning Systems. These applications coordinate and integrate information flow and activities within and/or between firm boundaries. The following sections detail the technologies investigated in the study and the adoption patterns of participating firms.

5.1.2 Adoption of Functional Technologies

The results for the first set of technologies examined, the 13 functional technologies, are presented in Tables 2-4. Bar-coding systems had the highest mean adoption rate (3.80) and was the only technology in the complete data set with more than half of the responding firms (56%) reported to have adopted it to "A Significant Amount" or "To A Great Extent" (Table 2). Warehouse Management Systems (WMS) and Electronic Commerce Technologies (ECT) have also been adopted to a comparatively greater extent than other technologies. More than 40% of respondents reported to have adopted these technologies to a significant or greater extent.

Bar-coding technology is considered a high payoff, low risk technology consisting of systems or products that are used in conjunction with many of the other technology systems to produce or utilize bar codes. Bar-coding technology assigns numbers to items to improve tracking and reporting of inventory through electronic identification. This technology is one of the most commonly used methods of electronic identification (Ream, 1998), and most items purchased today throughout the supply chain are bar-coded. Southbend Co., a manufacturer of ovens and ranges, installed a bar coding system with a

factory wide tracking system in 1997 (Malovany, 1998). The company has experienced increases in efficiency through reduction in labor costs, increases in inventory accuracy, faster turnaround for delivery of products, and elimination of physical inventorying of products. The president of the company estimates that bar coding has enable Southbend Co. to save $200,000 annually because it no longer shuts down to manually inventory its products (Malovany, 1998).

Warehouse management systems (WMS) are usually coupled with bar coding technology and provides the software to track and control the movement of inventory, from receiving to shipping, through the warehouse. Additionally, WMS manage the utilization of warehouse resources such as space, personnel and material handling equipment to improve productivity and efficiency. A recent survey found the three main reasons for adopting this technology are to reduce shipping errors, increase productivity, and track inventory (Fraza, 2002). The cost of a typical Warehouse Management System for a single warehouse facility with annual sales of $10 million is approximately $125,000 to $150,000 (Fraza, 2002) and is thus relatively inexpensive when compared to enterprise wide systems such as ERP. Applied Industrial Technologies, a billion dollar distributor has reduced errors and reports 99% accuracy rates after installation of WMS (Fraza, 2002).

Electronic commerce technology, a third highly adopted technology, provides the means for more efficient and accurate transmission of orders by enabling computer-based business transactions via private, proprietary networks such as Electronic Data Interchange (EDI) or the publicly accessible Internet. EDI, the most common form of interorganizational information system (IOS) and electronic commerce technology, has

Table 2: Adoption of Functional Technologies (Complete Set)

Technology	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amount	(%) Great Extent	No. of Obs. (1-5)	(%) NA or Missing
Bar-coding S.	3.80	1.20	2.8	13.1	18.7	20.6	35.5	97	9.3
Warehouse Management S.	3.53	1.47	12.1	11.2	16.8	12.1	34.6	93	13.1
Computer Aided Design	3.37	1.48	13.1	6.5	13.1	15.9	21.5	75	29.9
Electronic Commerce T.	3.26	1.24	10.3	14.0	27.1	25.2	16.8	100	6.5
Radio Frequency S.	3.10	1.56	21.5	7.5	15.9	14.0	22.4	87	18.7
Transportation Man. S.	2.97	1.40	15.0	22.4	16.8	14.0	17.8	92	14.0
Demand Forecasting Man.	2.87	1.34	15.9	17.8	18.7	16.8	11.2	86	19.6
Cust. Relationship Man.	2.72	1.33	21.5	20.6	20.6	17.8	10.3	97	9.3
Product Data Man.	2.64	1.39	23.4	13.1	19.6	11.2	10.3	83	22.4
Manufacturing Execution S	2.55	1.42	19.6	12.1	12.1	7.5	8.4	64	40.2
Auto. Quality Control S.	2.47	1.36	26.2	17.8	15.9	11.2	8.4	85	20.6
Supply Chain Event M.	2.37	1.36	29.0	20.6	15.0	8.4	9.3	88	17.8
Geo-coded Tracking S.	1.87	1.18	40.2	11.2	11.2	5.6	2.8	76	29.0

Table 3: Adoption of Functional Technologies (Manufacturers)

Technology	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amt.	(%) Great Extent	No. of Obs. (1-5)	(%) NA or Missing
Computer Aided Design	3.93	1.10	4.0	4.0	16.0	28.0	30.0	41	18.0
Bar-coding S.	3.85	1.23	4.0	14.0	12.0	26.0	38.0	47	6.0
Demand Forecasting Man.	3.14	1.23	10.0	16.0	28.0	20.0	14.0	44	12.0
Warehouse Management S.	3.13	1.45	16.0	18.0	20.0	14.0	24.0	46	8.0
Manufacturing Execution S	3.05	1.40	14.0	20.0	18.0	16.0	18.0	43	14.0
Cust. Relationship Man.	2.96	1.32	14.0	22.0	26.0	14.0	16.0	46	8.0
Radio Frequency S.	2.86	1.58	30.0	6.0	16.0	18.0	18.0	44	12.0
Electronic Commerce Tech	2.83	1.12	14.0	20.0	36.0	20.0	6.0	48	4.0
Transportation Man. S.	2.79	1.37	16.0	34.0	14.0	14.0	16.0	47	6.0
Product Data Man.	2.76	1.45	22.0	18.0	16.0	14.0	14.0	42	16.0
Auto. Quality Control S.	2.67	1.37	24.0	18.0	24.0	12.0	12.0	45	10.0
Supply Chain Event M.	2.18	1.21	32.0	28.0	12.0	12.0	4.0	44	12.0
Geo-coded Tracking S.	1.65	0.95	48.0	18.0	8.0	6.0	0.0	40	20.0

Table 4: Adoption of Functional Technologies (LSPs)

Technology	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amt.	(%) Great Extent	No. of Obs. (1-5)	(%) NA or Missing
Warehouse Management S	4.11	1.49	7.7	7.7	3.8	3.8	50.0	19	26.9
Electronic Commerce T.	4.04	0.98	0.0	3.8	26.9	19.2	38.5	23	11.5
Bar-coding S.	3.81	1.03	0.0	7.7	26.9	19.2	26.9	21	19.2
Radio Frequency S.	3.56	1.5	11.5	3.8	15.4	11.5	26.9	18	30.8
Transportation Man. S.	3.5	1.41	11.5	7.7	19.2	19.2	26.9	22	15.4
Supply Chain Event M.	3.05	1.58	19.2	7.7	15.4	11.5	19.2	19	26.9
Auto. Quality Control S.	2.47	1.37	23.1	11.5	11.5	15.4	3.8	17	34.6
Cust. Relationship Man.	2.41	1.33	30.8	15.4	15.4	19.2	3.8	22	15.4
Computer Aided Design	2.33	1.54	26.9	7.7	7.7	7.7	7.7	15	42.3
Geo-coded Tracking S.	2.25	1.34	26.9	7.7	15.4	7.7	3.8	16	38.5
Product Data Man.	2.12	1.26	26.9	11.5	15.4	3.8	3.8	16	38.5
Demand Forecasting Man.	2.06	1.09	23.1	26.9	3.8	11.5	0.0	17	34.6
Man. Execution S	1.56	0.88	23.1	3.8	7.7	0.0	0.0	9	65.4

Table 5: Adoption of Integrative Technologies

Technology	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amount	(%) Great Extent	No. of Obs. (1-5)	(%) NA or Missing
					Complete Data Set				
Enterprise Resource Plan.	2.92	1.59	29.0	7.5	15.0	16.8	20.6	95	11.2
Supply Chain Planning S.	1.98	1.32	47.7	11.2	10.3	9.3	5.6	90	15.9
					Manufacturers				
Enterprise Resource Plan.	3.12	1.55	26.0	8.0	16.0	24.0	24.0	49	2.0
Supply Chain Planning S.	2.00	1.27	46.0	12.0	14.0	10.0	4.0	43	14.0
					Logistics Service Providers				
Enterprise Resource Plan.	2.32	1.42	30.8	11.5	15.4	7.7	7.7	19	26.9
Supply Chain Planning S.	2.11	1.45	38.5	11.5	7.7	7.7	7.7	19	26.9

consistently been reported to improve customer service and lower cost (Droge and Germain, 2000) by facilitating communication and document exchange between supply chain partners (Dresner et al, 2001). Previous research has also shown a positive impact on inventory levels (Mukhopadhyay et al., 1995 ; Premkumar 2000; Lee and Whang, 2000) and inventory management (Yao et al. 2001).

Only 5 of the 13 functional technologies included in the survey had been adopted to "A Significant Amount" or "To A Great Extent" by more than one third of the responding firms. In addition to those mentioned above, Computer Aided Design technologies (CAD) and Radio Frequency technologies have also been adopted by a relatively large percentage of the respondents. CAD systems are generally stand-alone design tools that are used to design everything from parts to tools and fixtures. Therefore, CAD systems would be expected to be more applicable to manufacturing firms than to service providers as is reported below (Tables 3 and 4).

While a fairly large number of firms have adopted Radio Frequency (RF) technology to a significant or greater extent (36%), it has been adopted to a much less extent than the related bar coding technologies. These findings of lower adoption rates support Ream's (1998) contention that RF technology is less prominent than bar coding and initial costs significantly higher. RF technologies use radio waves to transfer detailed information from tags attached to items to a firm's information system. RF tags are superior to bar codes by allowing significantly more information to be stored and the capacity to easily update or alter information at any point along the supply chain without having to change the tag. Another advantage afforded by RF is its capacity to reliably operate in harsh environments (Ream, 1998). Dust, oil, or strong chemicals, which limit

bar coding's usefulness, do not affect the transmission of the radio waves. One of the companies that has implemented it reported, "Great success...(with RF)...in reducing paper costs and headcount...error rate cut by 50%."

The results indicate four of the five most adopted technologies involve managing inventory and information/document exchange. These two activities are vital to improving supply chain efficiency and suggest a substantial percentage of respondents have taken initial steps to electronically integrate their supply chain activities.

Conversely, many of the technologies have surprisingly low adoption rates (Table 2). Seven of the 13 technologies have been adopted "Not At All" or "Very Little" by more than one third of the responding firms. These include a diverse group of technologies such as Customer Relationship Management Systems, Automated Quality Control Systems, Product Data Management Systems, Demand Forecasting Management Systems, and Transportation Management Systems. The two technologies with the lowest adoption rates (Supply Chain Event Management Systems and Geo-coded Tracking systems) have been adopted to a very little extent or not at all by at least 50% of the respondents.

Supply Chain Event Management Systems (SCEM) is one of the most recently developed supply chain applications (developed two years ago) that improves a company's ability to share information across departments or firm boundaries (Morphy, 2002). AMR Research describes it as a "new category of technology that encompasses event management, workflow management, better information capabilities and, in some cases, business analytics" (Morphy, 2002). This technology application enables a company to access supply chain information in real time and immediately respond to

unplanned events. AMR Research suggests, "SCEM is likely to be a pervasive means of managing supply chain exceptions.... (and) is likely to also be a part of every SC application in the future" (AMR Research, 2001). However, these results indicate at this time most firms have yet to adopt this very new technology. The slowdown in the economy over the past two years has forced many companies to scale back their technology investments, and along with the newness of the technology, may explain the low adoption rate.

Geo-coded Tracking Systems achieved the lowest mean adoption rate in the complete data set. Geo-coded Tracking systems are satellite or cellular tracking devices most commonly used in trucks or trailers to ascertain position and feed the information to ancillary systems such as Transportation Management Systems or Warehouse Management Systems. These results suggest that this newer technology for tracking transport vehicles has not yet been widely adopted by most firms. More than 51% of the firms report that this technology had been adopted "Not At All" or "Very Little" and only 8% have adopted it to a significant or greater extent. Considering only the LSPs, the subgroup that may be expected to have adopted this technology to a greater extent than in the overall data set, only 11.5% of these respondents have adopted this technology to a significant or greater extent. It appears that most firms have adopted bar-coding technologies to track and control inventory but have not yet incorporated Geo-coded Tracking systems into their transportation operations.

One explanation for the low adoption rate for some of the technologies could be the diverse set of respondents. Perhaps many of these technologies are not appropriate for some of the groups within the sample of 107 responding firms. However, "Not

Applicable" was an option provided to the respondents and examination of Table 2 reveals that most technologies, except for Manufacturing Execution Systems (MES), Computer Aided Design Technologies (CAD), and Geo-coded Tracking Systems, had relatively low rates of missing or NA responses in the complete data set. These technologies might not be expected to be applicable to a large portion of the respondents as MES and CAD are more appropriate for manufacturers while Geo-coded tracking systems would be more appropriate for transportation providers. Furthermore, analysis of the manufacturers and logistics service providers (LSPs) separately indicate that many of these same technologies also have low adoption rates among both subgroups (Tables 3 and 4).

Examination of the two subgroups reveals important differences in the technologies adopted (Tables 3 and 4). While bar coding has been highly adopted by both groups, Computer Aided Design, Demand Forecasting Management Systems, and Manufacturing Execution Systems (MES) have all been adopted by manufacturers to a much greater extent than by logistics service providers. Manufacturing Execution Systems (MES), otherwise known as "shop-floor-control systems", provide a single, flexible platform for managing production, quality, inventory, and process controls (Bartholomew, 1998). MES software can deliver real-time visibility and control of manufacturing operations from equipment, materials, and people to the manufacturing process and assist companies in responding effectively to unexpected customer requirement changes. According to Bartholomew (1998), firms have been slow to adopt MES because of the cost and complexity of integrating it with other systems such as ERP. According to John Dertinger, systems manager from the mechanical products division of

Eastman Kodak Co. "MES came out in such a variety of flavors, there was mass confusion as to what it was. From a user perspective, companies had trouble quantifying what they would get from MES versus MRP and ERP" (Bartholomew, 1998). Perhaps this explains why only 34% of manufacturers have adopted this technology to a significant extent.

Conversely, logistics service providers have adopted Electronic Commerce Technologies, Warehouse Management Systems, Transportation Management Systems, and Supply Chain Event Management Systems substantially more than manufacturers. Transportation Management Systems (TMS) offer sophisticated planning algorithms and are intended to achieve enterprise-wide cargo control centers to address the complex transportation requirements between channel partners. It is not surprising that TMS has been highly adopted by many logistics service providers as they have, in the past, often begun serving clients by providing transportation services.

The highly adopted functional technologies in each of the sub-groups reveal that firms appear to adopt technologies primarily related to their core competencies in order to improve their primary functional activities. Bar coding technology is the one functional technology that crosses industry lines and is highly adopted by both manufactures and logistics service providers. However, few technologies have been adopted by more than half of the respondents in either subset. One explanation was provided by the Kellogg Company which has been preoccupied with its implementation of a company-wide ERP system. Its CIO explained, "We know we need an MES, but we've got enough to keep us busy" (Bartholomew, 1998). Another explanation could be the lack of results achieved by the new technologies. One software analyst stated it this way, "Most executives we

work with have been blindsided, burned, and frustrated by unexpected discrepancies between planning expectations and the realities achieved in their plants" (Bartholomew, 1998).

5.1.3 Adoption of Integrative Technologies

Integrative technologies are information systems used to coordinate and integrate information flow and activities within or between firm boundaries. The two technologies included in this category for this study are Enterprise Resource Planning Systems (ERP) and Supply Chain Planning Systems (SCP).

ERP offers a centralized information control system to integrate all company departments and functions. ERP covers such functions as capacity planning, cost and accounting, order entry, production management, inventory, and finance and has been described as "giant software systems" (Dornheim, 2001). SCP systems deal with long term strategic issues between collaborating partners by coordinating material and capacity resources across networks of facilities, suppliers, customers and trading partners. These systems integrate diverse applications and functions such as demand planning, supply and forecasting planning, scheduling, and distribution and transportation. The typical progression for companies would be to implement ERP and electronically integrate firm activities and then adopt SCP to integrate with partners.

ERP has been adopted by more than one third of the firms to "A Significant Amount" or "To A Great Extent" in the complete data set and almost half of the manufacturing firms (Table 5). As this application manages information flow through a

manufacturing environment, this is to be expected. According to Dornheim (2001), the demand for ERP systems has waned because of the difficulty of implementation and cost. This is corroborated by the data as most of the adopting firms implemented ERP 1-3 years ago (Table 6). Large firms can spend as much as $40 million over five years during the implementation of the technology (Dornheim, 2001). Many firms have experienced problems implementing ERP with perhaps the most well-known example being the Hershey case in 1999 when its Halloween candy sales were ruined because of difficulties with its new ERP system (Dornheim, 2001).

SCP systems have very low adoption rates in all three data sets (roughly 15% have adopted it significantly or greater) (Table 5). At least half of all respondents have adopted this technology to a very little extent or less. Several reasons may account for the extremely low adoption rates of this technology. Although cost is an important consideration, perhaps most important are the individual behaviors and characteristics of managers such as mistrust of supply chain partners and the focusing on individual logistics functions instead of the entire supply chain (Koch, 2002a). Both of these characteristics inhibit optimization of the entire supply chain and thus SCP adoption.

5.1.4 Functional Area Adoption

In addition to understanding which technologies have been adopted, we were also interested in determining which functional areas of the firm have been the highest adopters of technology in order to gain a more complete picture of supply chain technology adoption. Tables 7-9 detail the mean adoption rates and percentages of

adoption rates by functional area. Examination of the results indicate that Order Management and Inventory Management were two functional areas with high mean adoption rates and high percentages of respondents reporting a significant or greater extent of adoption. This was true in the complete data set as well as in the manufacturer and LSP subsets. However six of the eight functional areas had significant or high adoption rates of appropriate technologies by a substantial percentage of respondents (45% or more). The two areas that appear to lag are Research and Development and Manufacturing/Operations. R&D adoption rates are low in all three data sets, but half of the manufacturing firms report significant adoption of technologies in their manufacturing/operation function. Thus, according to the responses to this survey question, a large percentage of firms have adopted appropriate technologies throughout the firm.

The functional area adoption findings appear to partially substantiate the earlier technology adoption results for at least three of the highly adopting functional areas. The three areas include inventory management, order management and warehousing. Correspondingly, four of the five most adopted technologies involve managing inventory, orders or warehouse operations. Bar coding technologies, radio frequency technologies, and warehouse management systems are all used to track and control the movement of inventory through the warehouse and/or entire supply chain. Electronic commerce technology, which has also been highly adopted by responding firms, facilitates more efficient and accurate transmission of orders through the use of EDI or the

Table 6: Time of Implementation of Integrative Technologies

Technology	Not Implemented	Within Last Year	1-3 Yrs Ago	3-5 Yrs Ago	More than 5 Yrs Ago	No. of Obs. (1-5)	NA/ Missing
		Complete Data Set					
ERP	35.5	10.3	25.2	8.4	5.6	91	15.0
SCP	47.7	14.0	12.1	5.6	0.9	86	19.6
		Manufacturers					
ERP	38.0	10.0	32.0	10.0	8.0	49	2.0
SCP	50.0	14.0	12.0	10.0	2.0	44	12.0
		LSPs					
ERP	34.6	15.4	11.5	7.7	0.0	18	30.8
SCP	46.2	19.2	3.8	0.0	0.0	18	30.8

Table 7: Functional Area Adoption Rates (Complete Set)

Functional Area	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amount	(%) Great Extent	(%) NA or Missing	No. of Obs. (1-5)
Inventory Man.	3.82	1.03	1.9	5.6	28.0	24.3	29.0	11.2	95
Order Man.	3.82	1.06	2.8	6.5	22.4	29.0	28.0	11.2	95
Warehousing	3.68	1.26	5.6	10.3	20.6	18.7	30.8	14.0	92
Manufacturing/Ops	3.61	1.16	2.8	7.5	21.5	14.0	19.6	34.6	70
Customer Service	3.51	1.16	4.7	12.1	29.0	22.4	22.4	9.3	97
Accounting	3.47	1.29	8.4	15.9	18.7	26.2	25.2	5.6	101
Transportation	3.43	1.18	5.6	15.0	22.4	27.1	18.7	11.2	95
Research & Development	2.78	1.24	10.3	15.0	19.6	7.5	7.5	40.2	64

Table 8: Functional Area Adoption Rates (Manufacturers)

Functional Area	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amount	(%) Great Extent	(%) NA or Missing	No. of Obs. (1-5)
Order Man.	3.75	1.00	2.0	8.0	26.0	36.0	24.0	4.0	48
Manufacturing/Ops	3.67	1.07	2.0	10.0	28.0	26.0	24.0	10.0	45
Inventory Man.	3.67	0.87	0.0	6.0	36.0	32.0	18.0	8.0	46
Accounting	3.40	1.25	8.0	16.0	20.0	30.0	20.0	6.0	47
Customer Service	3.40	1.09	6.0	10.0	36.0	28.0	16.0	4.0	48
Warehousing	3.38	1.28	8.0	16.0	22.0	22.0	22.0	10.0	45
Transportation	3.23	1.15	8.0	18.0	26.0	32.0	12.0	4.0	48
Research & Development	3.03	1.29	10.0	20.0	22.0	14.0	14.0	20.0	40

Table 9: Functional Area Adoption Rates (Logistics Service Providers)

Functional Area	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amount	(%) Great Extent	(%) NA or Missing	No. of Obs. (1-5)
Inventory Man.	4.10	1.21	3.8	3.8	15.4	11.5	42.3	23.1	20
Order Man.	4.06	1.25	3.8	3.8	11.5	11.5	34.6	34.6	17
Warehousing	4.00	1.45	7.7	7.7	3.8	11.5	42.3	26.9	19
Transportation	3.78	1.24	7.7	3.8	19.2	26.9	30.8	11.5	23
Accounting	3.71	1.27	3.8	15.4	19.2	19.2	34.6	7.7	24
Manufacturing/Ops	3.64	1.50	3.8	7.7	7.7	3.8	19.2	57.7	11
Customer Service	3.57	1.40	3.8	19.2	19.2	3.8	34.6	19.2	21
Research & Development	2.25	1.04	7.7	11.5	7.7	3.8	0.0	69.2	8

publicly accessible Internet. It thus appears that at least half of the firms in the overall data set have attempted to manage their orders and inventory electronically by significantly adopting appropriate technologies in those functional areas.

However, it is interesting to note the discrepancies between the relatively high rates of adoption of appropriate technologies in many of the functional areas and the relatively low rates of adoption of many of the individual technologies included in Tables 2-4. Though respondents report a large percentage of firms have adopted appropriate technologies throughout the firm, only three of the 15 technologies have been significantly adopted by more than 40% of the respondents. Perhaps many managers do not believe in the need or understand the potential of many of these cutting edge technologies.

Research and Development consistently had the lowest adoption rates of appropriate technologies throughout all three data sets analyzed. Only 15% of the respondents in the complete data set reported that the R&D functional area had adopted the appropriate technologies to a significant or greater extent. There are many possible explanations for this. First, many of these firms may not engage in research and development. This functional area had the largest percentage of "Not Applicable" or missing responses with 40% responding thusly. Additionally, many of the technologies listed in the survey may not be applicable to R&D. With the exception of Computer Aided Design Systems, most are more appropriate to operations rather than research. Finally, perhaps supply chain managers in many firms may not be familiar with the activities and operations of the Research and Development functional area.

5.1.5 Automation of Processes

Another measure of technology employment used in the survey, percentage of automated transactions by functional area, largely corroborates the previous data regarding rates of adoption by functional areas (Tables 10-12). Again, Inventory Management, Order Management, and Warehousing are the areas with the highest rates of automation while R&D has the lowest. However it appears that the percentages of automated transactions are generally lower than measures of functional area adoption rates as shown in Tables 7-9. This could represent the lag period between adoption and full implementation of many of these complex technologies. For example, Koch (2002b) reports that most firms require one to three years to fully implement ERP. Tables 13-15 indicate that most functional area adoption of technologies has occurred within the past three years for most of the respondents. Thus, since most technologies have been recently adopted, perhaps firms have not yet maximized their use of these technologies. Another explanation could be that firms are choosing to automate only some of their transactions. Kraut et al. (1998) suggests the use of electronic networks improves inter-firm coordination but only for routine activities. Thus, firms may have found that some processes require personal coordination.

The two subsets of manufacturers and logistics service providers had similar patterns of process automation with the exception of two areas: automation of manufacturing/operations and warehousing (Tables 11 and 12). Expectedly, few logistics service providers have automated manufacturing operations while they report substantially greater automation of warehousing operations.

Noteworthy is the fact that no functional area was reported to have achieved a high degree of automation (greater than 60% of processes automated) by a majority of the respondents. Order Management had the largest percentage of high adopters with 48% of firms automating more than 60% of processes. It appears that there is significant opportunity for firms to expand their use of technology as measured by the automation of functional processes. Though R&D may continue to have low automated processes because of the personal interactions required for these processes, many of the other functional areas might be more automated to improve productivity and reduce costs.

Table 10: Automation of Processes by Functional Area (Complete Data Set)

Functional Area	Mean	SD	(%) 0-20%	(%) 21-40%	(%) 41-60%	(%) 61-80%	(%) 81-100%	No. of Obs. (1-5)	(%) NA or Missing
Inventory Man.	3.40	1.37	9.3	15.0	19.6	15.9	26.2	92	14.0
Order Management	3.35	1.44	15.0	11.2	14.0	23.4	24.3	94	12.1
Warehousing	3.29	1.41	11.2	17.8	13.1	19.6	22.4	90	15.9
Manufacturing/Ops.	3.17	1.30	8.4	8.4	17.8	13.1	11.2	63	41.1
Customer Service	2.98	1.46	20.6	16.8	15.0	20.6	17.8	97	9.3
Transportation	2.88	1.44	17.8	22.4	12.1	15.9	15.9	90	15.9
Accounting	2.84	1.50	26.2	13.1	13.1	21.5	15.0	95	11.2
Research & Development	2.27	1.26	20.6	9.3	13.1	6.5	2.8	56	47.7

Table 11: Automation of Processes by Functional Area (Manufacturers)

Functional Area	Mean	SD	(%) 0-20%	(%) 21-40%	(%) 41-60%	(%) 61-80%	(%) 81-100%	No. of Obs. (1-5)	(%) NA or Missing
Order Management	3.28	1.42	16.0	12.0	20.0	22.0	24.0	47	6.0
Inventory Man.	3.27	1.44	14.0	14.0	22.0	14.0	26.0	45	10.0
Manufacturing/Ops	3.19	1.26	12.0	10.0	28.0	22.0	14.0	43	14.0
Warehousing	2.96	1.28	14.0	20.0	24.0	20.0	12.0	45	10.0
Customer Service	2.96	1.47	24.0	14.0	14.0	26.0	16.0	47	6.0
Transportation	2.78	1.28	18.0	22.0	20.0	22.0	8.0	45	10.0
Accounting	2.67	1.54	34.0	8.0	16.0	18.0	14.0	45	10.0
Research & Development	2.38	1.28	26.0	14.0	18.0	12.0	4.0	37	26.0

Table 12: Automation of Processes by Functional Area (Logistics Service Providers)

Functional Area	Mean	SD	(%) 0-20%	(%) 21-40%	(%) 41-60%	(%) 61-80%	(%) 81-100%	No. of Obs. (1-5)	(%) NA or Missing
Warehousing	3.82	1.42	3.8	15.4	0.0	15.4	30.8	17	34.6
Inventory Man.	3.72	1.36	3.8	15.4	3.8	19.2	26.9	18	30.8
Order Management	3.17	1.50	15.4	7.7	11.5	19.2	15.4	18	30.8
Transportation	3.14	1.61	15.4	23.1	11.5	3.8	30.8	22	15.4
Manufacturing/Ops	3.13	1.73	7.7	3.8	7.7	0.0	11.5	8	69.2
Accounting	3.09	1.54	19.2	15.4	7.7	23.1	19.2	22	15.4
Customer Service	3.00	1.66	23.1	15.4	11.5	7.7	26.9	22	15.4
Research & Development	1.83	1.17	11.5	7.7	0.0	3.8	0.0	6	76.9

Table 13: Time of Implementation by Functional Area (Complete Data Set)

Functional Area	Mean	S.D.	(%) Not Imp	(%) Within Last Yr	(%) 1-3 Yrs Ago	(%) 3-5 Yrs Ago	(%) More than 5 Yrs	No. of Obs. (1-5)	(%) NA or Missing
Order Man.	3.05	1.06	2.8	26.2	29.9	15.9	10.3	91	15.0
Inventory Man.	2.98	1.22	8.4	24.3	23.4	15.0	12.1	89	16.8
Manufacturing/Ops	2.95	1.18	7.5	14.0	15.0	16.8	4.7	62	42.1
Warehousing	2.93	1.26	9.3	25.2	18.7	14.0	12.1	85	20.6
Customer Service	2.72	1.18	14.0	24.3	28.0	11.2	8.4	92	14.0
Accounting	2.69	1.21	14.0	24.3	26.2	8.4	9.3	88	17.8
Transportation	2.65	1.21	14.0	27.1	25.2	5.6	10.3	88	17.8
Research & Development	2.47	1.34	16.8	11.2	15.0	3.7	6.5	57	46.7

Table 14: Time of Implementation by Functional Area (Manufacturers)

Functional Area	Mean	S.D.	(%) Not Imp	(%) Within Last Yr	(%) 1-3 Yrs Ago	(%) 3-5 Yrs Ago	(%) More than 5 Yrs	No. of Obs. (1-5)	(%) NA or Missing
Manufacturing/Ops	3.16	1.10	8.0	16.0	24.0	34.0	6.0	44	12.0
Order Management	3.06	1.03	2.0	30.0	32.0	20.0	10.0	47	6.0
Inventory Man.	3.02	1.14	8.0	24.0	28.0	22.0	10.0	46	8.0
Warehousing	2.95	1.29	14.0	20.0	22.0	20.0	12.0	44	12.0
Customer Service	2.74	1.21	18.0	18.0	38.0	10.0	10.0	47	6.0
Accounting	2.67	1.15	16.0	20.0	32.0	12.0	6.0	43	14.0
Transportation	2.67	1.24	18.0	24.0	28.0	10.0	10.0	45	10.0
Research & Development	2.45	1.34	26.0	16.0	24.0	4.0	10.0	40	20.0

Table 15: Time of Implementation by Functional Area (Logistics Service Providers)

Functional Area	Mean	S.D.	(%) Not Imp	(%) Within Last Yr	(%) 1-3 Yrs Ago	(%) 3-5 Yrs Ago	(%) More than 5 Yrs	No. of Obs. (1-5)	(%) NA or Missing
Transportation	3.10	1.29	3.8	26.9	23.1	3.8	19.2	20	23.1
Warehousing	3.08	1.38	3.8	19.2	7.7	7.7	11.5	13	50.0
Manufacturing/Ops	3.00	1.67	3.8	7.7	3.8	0.0	7.7	6	76.9
Accounting	2.95	1.36	7.7	26.9	23.1	0.0	19.2	20	23.1
Inventory Man.	2.87	1.36	7.7	19.2	15.4	3.8	11.5	15	42.3
Order Management	2.71	1.10	7.7	23.1	19.2	11.5	3.8	17	34.6
Research & Development	2.57	1.51	7.7	7.7	3.8	3.8	3.8	7	73.1
Customer Service	2.47	1.17	15.4	26.9	15.4	11.5	3.8	19	26.9

5.1.6 Benefits of Technology Adoption

In addition to understanding adoption patterns, we were also interested in the benefits provided by these 15 supply chain technologies. We examined cost savings resulting from the adoption of these technologies as well as improvements to fundamental logistics measures, integration and overall supply chain performance.

5.1.7 Functional Area Cost Savings

One of the primary purposes of adopting new technologies for many firms is to reduce operational costs (Brynjolfsson, 1994). In the complete data set, warehousing appears to achieve the greatest cost savings with more than 38% of the respondents reporting a significant or greater level of cost savings resulting from adoption and implementation of supply chain technology (Table 16). The areas of Inventory Management and Order Management have also attained significant or greater savings for more than 30% of the respondents in the overall sample. Several respondents supported these findings with comments such as, "Gained significant cost savings by integrating information from Order Processing, Manufacturing, Shipping, and 3PL vendor."

The four areas ranked high in cost savings were also the four areas that have high levels of adoption and automation (Warehousing, Inventory Management, Order Management, Manufacturing/Operations). However, it appears that not all firms with high adoption rates have reaped significant cost savings. For example, 53% of

Table 16: Functional Area Cost Savings (Complete Data Set)

Functional Area	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amount	(%) Great Extent	No. of Obs. (1-5)	(%) NA or Missing
Warehousing	3.25	1.20	8.4	12.1	16.8	29.0	9.3	81	24.3
Inventory Man.	3.20	1.16	6.5	14.0	27.1	18.7	12.1	84	21.5
Order Management	3.19	1.09	4.7	18.7	22.4	26.2	8.4	86	19.6
Manufacturing/Ops	3.05	1.22	8.4	9.3	19.6	14.0	7.5	63	41.1
Transportation	2.93	1.12	9.3	18.7	22.4	22.4	4.7	83	22.4
Customer Service	2.89	1.21	12.1	17.8	23.4	18.7	7.5	85	20.6
Accounting	2.73	1.13	13.1	23.4	25.2	17.8	4.7	90	15.9
Research & Development	2.04	1.04	19.6	16.8	12.1	1.9	1.9	56	47.7

Table 17: Functional Area Cost Savings (Manufacturers)

Functional Area	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amount	(%) Great Extent	No. of Obs. (1-5)	(%) NA or Missing
Order Management	3.21	1.12	4.0	22.0	20.0	28.0	10.0	42	16.0
Manufacturing/Ops	3.18	1.03	6.0	12.0	30.0	26.0	6.0	40	20.0
Inventory Man.	3.18	1.03	4.0	16.0	30.0	22.0	8.0	40	20.0
Transportation	2.90	1.17	10.0	20.0	22.0	20.0	6.0	39	22.0
Warehousing	2.87	1.14	12.0	16.0	20.0	26.0	2.0	38	24.0
Customer Service	2.83	1.27	14.0	24.0	16.0	22.0	8.0	42	16.0
Accounting	2.68	1.13	12.0	28.0	20.0	18.0	4.0	41	18.0
Research & Development	2.09	1.12	26.0	22.0	16.0	2.0	4.0	35	30.0

Table 18: Functional Area Cost Savings (Logistics Service Providers)

Functional Area	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amount	(%) Great Extent	No. of Obs. (1-5)	(%) NA or Missing
Warehousing	3.31	1.25	7.7	7.7	11.5	26.9	7.7	16	38.5
Transportation	3.05	1.12	7.7	19.2	19.2	30.8	3.8	21	19.2
Inventory Man.	2.94	1.39	15.4	7.7	15.4	19.2	7.7	17	34.6
Order Management	2.81	1.33	11.5	15.4	15.4	11.5	7.7	16	38.5
Customer Service	2.78	1.52	23.1	7.7	7.7	23.1	7.7	18	30.8
Accounting	2.73	1.20	15.4	23.1	19.2	23.1	3.8	22	15.4
Manufacturing/Ops	2.33	1.50	15.4	3.8	7.7	3.8	3.8	9	65.4
Research & Development	1.63	0.92	19.2	3.8	7.7	0.0	0.0	8	69.2

respondents reported an adoption rate of significant or greater for the Inventory Management function, while 42% reported significant automation rates (greater than 60% of processes automated). However, only 31% reported significant or higher cost savings. For Order Management, the results are similar in that 57% reported significant adoption, 48% reported significant automation, yet only 35% reported significant savings. The data suggests the warehousing function may have fared relatively better than other functional areas. Fifty percent of respondents reported an adoption rate of significant or higher in the warehousing function, while 42% reported significant automation rates. Levels of significant cost savings, reported by 38% of respondents, approached levels of automation for warehousing.

The Manufacturing/Operations function has also achieved relatively high levels of savings. In the overall data set, 34% of respondents reported significant or greater adoption of technology in this functional area (Table 7) and 24% report significant automation (Table 10). Surprisingly, 22% of the respondents reported significant cost savings; almost the same percentage of significant automation (Table 16). Examination of the manufacturer data only because of the high percentage of NA or missing responses in the overall data set yields similar results. Fifty percent of manufacturers have significantly (or greater) adopted appropriate manufacturing/operations technologies (Table 8) and 36% have achieved significant process automation (Table 11). Accordingly, 32% of manufacturers have achieved significant cost savings in this functional area (Table 17).

Considering only logistics service providers, both Transportation and Warehousing functional areas appear to have achieved important cost savings (Table 18).

Fifty-eight percent of LSP respondents reported a significant or higher adoption rate of supply chain technology in the Transportation area (Table 9), while 35% reported significant automation rates (Table 12). Surprisingly, 35% also reported significant or greater cost savings in this functional area (Table 18). The Warehousing functional area is another source of savings for LSPs. Fifty-four percent reported significant or higher adoption rates of technology and 46% automation rates for the warehousing function. Yet 35% reported significant or greater cost savings. These results suggest LSPs have achieved relatively substantial cost savings from their investments in the four most adopted supply chain technologies: Warehouse Management Systems, Electronic Commerce Technologies, Bar-coding Systems, and Transportation Management Systems (Table 4).

Not surprisingly, R&D has produced the least cost savings. This is consistent with the generally low levels of adoption and automation. More than 36% of the respondents claim that technology adoption in this functional area has produced little or no cost savings (Table 16).

5.1.8 Logistics Metric Improvements

In addition to cost savings, firms adopt technology to improve operational performance. The three categories of supply chain performance examined in this study were fundamental logistics metrics, integration between partners, and performance of the entire supply chain (Tables 19-25). The two logistics measurements, in the complete data set, that were rated to be significantly or greater improved by 50% or more of the

respondents were shipment accuracy and customer service. Respondents also reported substantial improvement in customer satisfaction resulting from the adoption of supply chain technology systems.

Improvement in shipment accuracy from information technology adoption has been widely reported (Allen et al., 1992; Stern and Kaufmann, 1985; Fraza 2002), and is confirmed by this study. Fraza (2002) reports that a recent WMS survey found one of the primary reasons for adopting this technology is to reduce shipping errors. Information technology increases accuracy by automating redundant tasks and removing the human error factor. It appears that one of the primary goals of technology adoption has been accomplished to a significant degree by a large number of respondents.

In addition to cost savings, Brynjolfsson (1994) found one of the primary motivations for investing in information technology was improvement in operational measures such as customer service. Customer service, although scoring relatively low on the functional area adoption question as well as on the automation of processes question, was reported to have been significantly or greater improved by half of the respondents. These results support previous research which has shown a positive impact of interorganizational information systems on customer service (Stern and Kaufmann, 1985; Mackay and Rosier, 1996). It is possible that customer service and satisfaction is impacted by the adoption of a variety of technologies in a variety of functional areas and not just the result of automation of processes in the customer service functional area. Additionally, perhaps this question could be better addressed by the customers instead of the firms adopting these technologies. Perhaps the customers could provide more objective opinions and insight into this question.

Table 19: Supply Chain Metrics Improvements (Complete Data Set)

Measurement	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amt.	(%) Great Ext.	No. of Obs. (1-5)	(%) NA or Missing
Improve Shipment Accuracy	3.78	0.93	2.8	3.7	19.6	41.1	16.8	90	15.9
Improve Customer Service	3.63	0.88	0.9	6.5	30.8	35.5	14.0	94	12.1
Increase Cust. Satisfaction	3.54	0.91	0.9	8.4	34.6	29.9	14.0	94	12.1
Understand Cost To Serve	3.37	1.04	3.7	11.2	32.7	24.3	13.1	91	15.0
Reduce Cust. Order Costs	3.36	1.11	5.6	11.2	29.9	25.2	14.0	92	14.0
Reduce Lead Time	3.35	1.06	5.6	10.3	28.0	30.8	10.3	91	15.0
Improve Turnover	3.27	1.05	5.6	10.3	26.2	27.1	7.5	82	23.4
Reduce Inventory Levels	3.14	1.04	4.7	15.9	27.1	23.4	6.5	83	22.4
Distinction of Inventory	3.09	1.27	8.4	12.1	15.9	15.9	9.3	66	38.3
Reduce Order Costs	3.05	1.04	3.7	20.6	33.6	13.1	9.3	86	19.6
Improve On-time Delivery	3.00	0.96	5.6	16.8	34.6	20.6	3.7	87	18.7
Product to Market Speed	2.97	1.09	9.3	11.2	31.8	16.8	5.6	80	25.2

Table 20: Supply Chain Metrics Improvements (Manufacturers)

Measurement	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amt.	(%) Great Ext.	No. of Obs. (1-5)	(%) NA or Missing
Improve Shipment Accuracy	3.70	0.88	2.0	4.0	26.0	42.0	14.0	44	12.0
Improve Customer Service	3.56	0.87	0.0	8.0	38.0	30.0	14.0	45	10.0
Increase Cust. Satisfaction	3.48	0.89	0.0	10.0	42.0	26.0	14.0	46	8.0
Understand Cost To Serve	3.36	1.11	4.0	16.0	30.0	24.0	16.0	45	10.0
Reduce Lead Time	3.33	1.09	8.0	8.0	30.0	34.0	10.0	45	10.0
Improve Turnover	3.19	1.04	8.0	8.0	34.0	28.0	6.0	42	16.0
Distinction of Inventory	3.18	1.30	10.0	16.0	14.0	26.0	12.0	39	22.0
Reduce Cust. Order Costs	3.16	1.07	6.0	16.0	36.0	22.0	10.0	45	10.0
Reduce Inventory Levels	3.12	1.05	8.0	12.0	34.0	26.0	6.0	43	14.0
Improve On-time Delivery	3.00	1.04	8.0	20.0	30.0	28.0	4.0	45	10.0
Reduce Order Costs	2.95	0.92	2.0	26.0	38.0	14.0	6.0	43	14.0
Product to Market Speed	2.79	1.08	14.0	14.0	38.0	16.0	4.0	43	14.0

Table 21: Supply Chain Metrics Improvements (Logistics Service Providers)

Measurement	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amt.	(%) Great Ext.	No. of Obs. (1-5)	(%) NA or Missing
Improve Shipment Accuracy	4.05	0.71	0.0	0.0	15.4	38.5	19.2	19	26.9
Reduce Cust. Order Costs	3.89	0.94	0.0	3.8	23.1	23.1	23.1	19	26.9
Increase Cust. Satisfaction	3.85	0.93	0.0	7.7	15.4	34.6	19.2	20	23.1
Improve Customer Service	3.80	0.89	0.0	7.7	15.4	38.5	15.4	20	23.1
Understand Cost To Serve	3.58	0.84	0.0	7.7	23.1	34.6	7.7	19	26.9
Improve Turnover	3.50	1.29	3.8	11.5	3.8	23.1	11.5	14	46.2
Distinction of Inventory	3.40	1.07	0.0	7.7	15.4	7.7	7.7	10	61.5
Reduce Lead Time	3.33	1.14	3.8	15.4	11.5	30.8	7.7	18	30.8
Product to Market Speed	3.29	1.07	3.8	7.7	15.4	23.1	3.8	14	46.2
Reduce Inventory Levels	3.23	1.17	0.0	19.2	7.7	15.4	7.7	13	50.0
Improve On-time Delivery	2.93	1.10	3.8	19.2	15.4	15.4	3.8	15	42.3
Reduce Order Costs	2.76	1.03	3.8	26.9	19.2	11.5	3.8	17	34.6

Table 22: Supply Chain Integration Improvements (Complete Data Set)

Measurement	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amt.	(%) Great Extent	No. of Obs. (1-5)	(%) NA or Missing
Improve Info Sharing	3.40	1.05	3.7	13.1	26.2	30.8	12.1	92	14.0
Improve Coordination	3.37	0.97	3.7	8.4	36.4	27.1	10.3	92	14.0
Increase Commitment	3.24	1.00	1.9	18.7	32.7	22.4	10.3	92	14.0
Increase Trust	3.07	0.94	4.7	16.8	36.4	24.3	3.7	92	14.0

Table 23: Supply Chain Integration Improvements (Manufacturers)

Measurement	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amt.	(%) Great Extent	No. of Obs. (1-5)	(%) NA or Missing
Improve Coordination	3.39	0.97	2.0	12.0	36.0	26.0	12.0	44	12.0
Improve Info Sharing	3.33	1.06	2.0	20.0	30.0	26.0	14.0	46	8.0
Increase Commitment	3.13	0.92	0.0	24.0	38.0	20.0	8.0	45	10.0
Increase Trust	2.96	0.98	6.0	22.0	36.0	22.0	4.0	45	10.0

Table 24: Supply Chain Integration Improvements (Logistics Service Providers)

Measurement	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amt.	(%) Great Extent	No. of Obs. (1-5)	(%) NA or Missing
Improve Info Sharing	4.00	0.88	0.0	3.8	15.4	30.8	23.1	19	26.9
Improve Coordination	3.80	0.77	0.0	0.0	30.8	30.8	15.4	20	23.1
Increase Commitment	3.74	1.10	3.8	7.7	7.7	38.5	15.4	19	26.9
Increase Trust	3.45	0.83	0.0	11.5	23.1	38.5	3.8	20	23.1

Table 25: Supply Chain Performance Improvements

Measurement	Mean	S.D.	(%) Highly Neg.	(%) Some what Neg.	(%) Neut.	(%) Some what Pos.	(%) Highly Pos.	No. of Obs. (1-5)	(%) NA or Missing
Supply Chain Performance (Complete Set)	4.11	0.65	0.0	0.9	11.2	53.3	22.4	94	12.1
Supply Chain Performance (Manufacturers)	3.96	0.52	0.0	0.0	14.0	66.0	10.0	45	10.0
Supply Chain Performance (LSP)	4.25	0.91	0.0	3.8	11.5	23.1	38.5	20	23.1

Previous research indicates information technology may lead to reduced inventory levels (Mukhopadhyah et al., 1995; Stank et al., 1999). It is interesting to note the contrasts between functional area adoption rates and inventory measure improvements. Fifty-three percent of respondents reported that their firm's Inventory Management Functional area has adopted appropriate supply chain technologies to a significant or greater extent (Table 7). Relatedly, 50% of respondents reported their firms Warehousing area have adopted appropriate technologies to a significant or greater extent (Table 7). In contrast, 30% of respondents indicated significant or greater reductions in inventory levels, 35% reported significant improvement in inventory turnover, and 41% asserted reductions in lead time (Table 19). These results suggest while many firms have improved their inventory levels, not all firms that have significantly invested in the inventory management area have achieved significant improvements.

The Order Management Function has also seen substantial technology adoption for a majority of the firms in the survey (Table 7). As a result of technology adoption, the majority of firms (58%) have seen a significant improvement in shipping accuracy. However, the impact on reducing order processing costs has been much less with only 39% of firms reporting significant savings on customer order processing and only 22% reporting significant savings in placing orders with suppliers. This provides only moderate support to earlier studies which report information technology reduces administration costs (Mackay and Rosier (1996), purchase order costs (Sutton, 1997) and should be a key driver of cost savings (Clemons and Row, 1993).

Results are similar for both manufacturers and logistics service providers. For manufacturers, five of the first six supply chain measure improvements are the same as

for the overall sample, and for LSPs, the top five measures are identical to the overall sample (Tables 20-21).

5.1.9 Supply Chain Integration

Another area suggested to be impacted by technology is the degree of integration between supply chain partners (Gustin et al., 1995). The degree of integration in this survey was examined by measuring improvements in information sharing, coordination of logistics activities, trust between partners and commitment between supply chain partners. These results indicate supply chain technology impacts information sharing and coordination of logistics activities more than commitment and trust as indicated by both mean improvement rates and percentages of significant or greater improvements (Table 22). This would seem logical as it has been proposed that trust and commitment are components of the transaction climate and are theorized to be precursors to supply chain technologies (Reve and Stern, 1986; Premkumar and Ramamurthy, 1995). However, information sharing (Lee et al 1997; Chen et al. 2000; Cachon and Fisher 2000; Lee et al. 2000; Gavirneni et al. 1999;) and coordination (Stank et al., 1999; Kraut et al., 1998; Kekre and Mukhopadhyah, 1992) are behavioral activities that are theorized to be improved as a result of technology adoption. One respondent emphasized the importance of technology to collaboration when he commented, "Collaboration becomes second nature with the sharing of coordinated information. In our environment, where we are operating in China and our customers are on other continents, we have no other options than to implement and integrate technology." However, not all firms have successfully

integrated activities. For example, one respondent stated, "High expectations with software vendors, only to find they are selling 'vaporware.' Technologies do not integrate as expected, especially between companies for collaboration."

For the subsets, it appears that the same is generally true (Tables 23-24). Information sharing and coordination are generally improved more than commitment and trust. It is interesting to note that the LSPs have generally achieved higher levels of integration than manufacturers and the overall data set. It is conceivable that logistics service providers seek and achieve a higher level of integration and longer-term relationships with partners through adoption of supply chain technology in order to enhance supply chain operations. Relatedly, one prominent difference between technologies adopted by Manufacturers versus LSPs is the high rate of adoption of Electronic Commerce Technologies among LSPs (Tables 3-4). Electronic Commerce Technologies such as EDI have been suggested to positively impact integration of firms along the supply chain (Stank et al., 1999) which may explain these results.

5.1.10 Entire Supply Chain Performance

The final benefit investigated by the survey was the impact of supply chain technology on the performance of the entire supply chain. In the overall data set as well as for manufacturing firms, the majority of the respondents reported the performance of their entire supply chain had been somewhat positively impacted as a result of supply chain technology adoption (Table 25). However, LSPs had a substantially higher percentage of respondents reporting a highly positive impact on the performance of their

entire supply chain (Table 25). As with the integration results, the data suggest that LSPs believe greater benefits have been achieved through the adoption of supply chain technology than manufacturers.

5.1.11 Future Adoption of Supply Chain Technologies

The last adoption question focused on technologies implemented or planned to be adopted within one year (Table 26). When compared to responses from the earlier technology adoption question (See Table 4), the results of this question indicate those technologies that are planned to be adopted by respondents in the next 12 months. While most of the technologies had similar patterns of reporting to the two questions, four technologies are expected to be adopted by at least a small portion of firms within the next year. Those four include electronic commerce technologies, demand forecasting management systems, supply chain planning systems (SCP), and transportation management systems. SCP has the highest expectation for adoption with almost twice as many respondents (29% vs. 15%) reporting significant or higher adoption rates to this question than the earlier adoption question (Table 4).

Manufacturers indicate similar expectations as they plan to invest in electronic commerce technologies, supply chain planning systems and demand forecasting systems (Table 27). New technology adoption by logistics service providers appears to be limited as only a small portion of responding firms report adoption expectations for supply chain planning systems and product data management systems (Table 28).

Table 26: Technologies Implemented/Planned To Be Adopted (Complete Data Set)

Technology	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amt.	(%) Great Extent	No. of Obs. (1-5)	(%) NA or Missing
Bar-coding S.	3.80	1.28	5.6	6.5	18.7	14.0	32.7	83	22.4
Warehouse Man. S.	3.67	1.38	7.5	11.2	13.1	15.0	31.8	84	21.5
Electronic Commerce T.	3.56	1.25	7.5	9.3	15.0	28.0	20.6	86	19.6
Demand Forecasting M.	3.32	1.42	11.2	10.3	14.0	16.8	19.6	77	28.0
Transportation Man. S.	3.23	1.54	15.9	14.0	8.4	16.8	23.4	84	21.5
Radio Frequency S.	3.20	1.61	20.6	4.7	12.1	14.0	23.4	80	25.2
Computer Aided Design	2.98	1.60	19.6	4.7	9.3	13.1	15.0	66	38.3
ERP	2.84	1.69	29.9	7.5	13.1	5.6	24.3	86	19.6
Cust. Relationship Man.	2.83	1.47	22.4	12.1	21.5	9.3	16.8	88	17.8
Supply Chain Planning S.	2.76	1.48	24.3	11.2	14.0	16.8	12.1	84	21.5
Man. Execution S.	2.61	1.52	19.6	8.4	11.2	5.6	10.3	59	44.9
Product Data Man.	2.47	1.55	32.7	7.5	12.1	9.3	12.1	79	26.2
Supply Chain Event M.	2.40	1.41	29.0	15.0	14.0	8.4	9.3	81	24.3
Auto. Quality Control S.	2.33	1.34	26.2	11.2	18.7	3.7	7.5	72	32.7
Geo-coded Tracking S.	2.06	1.31	32.7	13.1	10.3	4.7	5.6	71	33.6

Table 27: Technologies Implemented or Planned To Be Adopted (Manufacturers)

Technology	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amt.	(%) Great Extent	No.of Obs. (1-5)	(%) NA or Missing
Bar-coding S.	3.78	1.41	8.0	10.0	12.0	14.0	38.0	41	18.0
Computer Aided Design	3.43	1.50	14.0	6.0	12.0	18.0	24.0	37	26.0
Warehouse Management S.	3.42	1.47	12.0	14.0	16.0	14.0	30.0	43	14.0
Electronic Commerce T.	3.30	1.26	10.0	12.0	22.0	26.0	16.0	43	14.0
ERP	3.18	1.70	26.0	8.0	14.0	8.0	34.0	45	10.0
Cust. Relationship Man.	3.00	1.60	24.0	14.0	16.0	10.0	26.0	45	10.0
Transportation Man. S.	2.98	1.46	16.0	24.0	10.0	18.0	18.0	43	14.0
Radio Frequency S.	2.98	1.65	28.0	6.0	12.0	16.0	22.0	42	16.0
Demand Forecasting M.	3.40	1.43	12.0	12.0	16.0	18.0	26.0	42	16.0
Supply Chain Planning S.	2.84	1.43	24.0	12.0	18.0	22.0	12.0	44	12.0
Product Data Man.	2.74	1.59	30.0	12.0	12.0	14.0	18.0	43	14.0
Man. Execution S.	2.67	1.60	30.0	14.0	14.0	6.0	20.0	42	16.0
Auto. Quality Control S.	2.56	1.36	24.0	16.0	26.0	4.0	12.0	41	18.0
Supply Chain Event M.	2.25	1.37	36.0	20.0	16.0	6.0	10.0	44	12.0
Geo-coded Tracking S.	1.90	1.25	42.0	18.0	8.0	4.0	6.0	39	22.0

Table 28: Technologies Implemented or Planned To Be Adopted (Logistics Service Providers)

Technology	Mean	S.D.	(%) Not at All	(%) Very Little	(%) Some what	(%) Sig. Amt	(%) Great Extent	No of Obs. (1-5)	(%) NA or Missing
Warehouse Management S.	4.19	1.11	0.0	7.7	7.7	11.5	34.6	16	38.5
Bar-coding S.	3.76	0.97	0.0	3.8	26.9	15.4	19.2	17	34.6
Electronic Commerce T.	3.68	1.25	3.8	11.5	11.5	23.1	23.1	19	26.9
Transportation Man. S.	3.68	1.49	11.5	3.8	11.5	15.4	30.8	19	26.9
Supply Chain Event M.	3.13	1.46	11.5	7.7	11.5	15.4	11.5	15	42.3
Radio Frequency S.	3.13	1.68	15.4	7.7	7.7	7.7	19.2	15	42.3
Demand Forecasting Man.	3.10	1.52	7.7	7.7	3.8	11.5	7.7	10	61.5
Cust. Relationship Man.	2.79	1.36	15.4	15.4	23.1	7.7	11.5	19	26.9
Supply Chain Planning S.	2.75	1.57	19.2	11.5	7.7	11.5	11.5	16	38.5
Auto. Quality Control S.	2.62	1.50	15.4	11.5	7.7	7.7	7.7	13	50.0
Man. Execution S.	2.29	1.25	11.5	0.0	11.5	3.8	0.0	7	73.1
Geo-coded Tracking S.	2.29	1.38	23.1	7.7	11.5	7.7	3.8	14	46.2
Product Data Man.	2.23	1.30	23.1	3.8	11.5	11.5	0.0	13	50.0
ERP	2.13	1.26	26.9	11.5	15.4	3.8	3.8	16	38.5
Computer Aided Design	1.75	1.22	30.8	3.8	3.8	7.7	0.0	12	53.8

It appears responding firms have moderate plans for additional technologies over the next twelve months. It is interesting to note that supply chain planning systems is the one technology that is expected to be adopted by at least a small percentage of firms in all three data sets. Perhaps some firms have begun to realize the need to progress beyond just functional adoption of technologies and begin more complete electronic integration throughout the supply chain.

5.1.12 Summary

These results provide important insight into the current state of supply chain technology adoption and utilization. The results indicate that the majority of firms realize the potential of supply chain technology and have begun to adopt a variety of information systems.

One of the key advantages of electronic integration is the speed and proficiency of exchanging information with partners in order to better control inventory throughout the supply chain (Levary, 2000; Stank et al., 1999). A sizable portion of firms have adopted technologies to improve functional activities and operations, but have not yet adopted those technologies that integrate the entire supply chain. These results confirm an earlier study which suggests firms are employing "internally focused" supply chain technology such as warehouse management systems and demand forecasting (Kilgore, 2001).

Four of the five most adopted technologies involve managing inventory and information/document exchange within and between firm boundaries. These are two core

activities of supply chain management and suggest many firms have taken initial steps to improve operational efficiency and reduce costs. However, few companies have adopted the integrating technologies such as ERP and SCP that electronically link members of the supply chain and provide end-to-end electronic communication and automatic data capture and transmission capabilities. These findings confirm recent claims by Bushnell (2002) who reported that most firms have adopted bar codes and electronic documents but fewer than 20% have integrated their warehouse management and enterprise wide systems.

This focus on functional technologies by most companies is further confirmed by comparing the highly adopted technologies for manufacturers with logistics service providers. Computer Aided Design, Demand Forecasting Management Systems, and Manufacturing Execution Systems (MES) have all been adopted by manufacturers to a much greater extent than by logistics service providers. Conversely, logistics service providers have adopted Electronic Commerce Technologies, Warehouse Management Systems, Transportation Management Systems, and Supply Chain Event Management Systems substantially more than manufacturers. The subsets have also adopted integrative technologies to a substantially different degree as well. Manufacturers have adopted ERP to a much greater extent than SCP while LSPs have adopted ERP and SCP to the same extent. This provides further evidence of the continued focus by most firms on, and adoption of, technologies that improve functional performance and efficiency and not the efficiency of the entire supply chain.

While adoption of many technologies has been moderate, reported benefits of adoption have also generally been quite modest. The four functional areas with reportedly

high levels of adoption and automation (Warehousing, Inventory Management, Order Management, Manufacturing/Operations) also were the four areas that ranked high in cost savings. However, reported adoption rates were often substantially higher than reported cost savings. For example, 53% of respondents reported an adoption rate of significant or greater for the Inventory Management function, but only 31% reported significant or higher cost savings. Similar results were reported for many of the functional areas.

Improvements to logistics performance measures also appear to lag adoption rates for many firms as well. For example, fifty percent of respondents reported their firms warehousing area has adopted appropriate technologies to a significant or greater extent. In contrast, 30% of respondents indicated significant or greater reductions in inventory levels, 35% reported significant improvement in inventory turnover, and 41% assert reductions in lead time. It thus appears that not all firms with high adoption rates have reaped significant benefits or cost savings. One disappointed respondent claimed, "The proliferation of buzzwords/terms/theories that are a natural by-product of the marketing activities of system purveyors serve to confuse and complicate efforts to recognize and improve capabilities…" Another LSP reported, "The more complex the system, the less likely it will be a success or fully implemented. Many disparate systems and failures have companies second guessing their decisions." Finally one respondent simply stated, "The expectations are in general higher than the actual result."

Though there were several negative comments from disgruntled respondents, many respondents reported favorable results from technologies his/her firm had adopted. For example, one manufacturer reported, "The expected benefits of increasing our percent of business conducted via e-commerce has far exceeded our original objectives -

improved cost structure, reliability and information access to name a few." Another stated, "Implementation of supply chain technology has allowed this company the opportunity to build strong relationships with several key customers by allowing us the opportunity to reduce lead time for them. In several instances, we have achieved sole supplier status by showing them the advantage our supply chain. We have also had the opportunity to reduce inventory carrying cost, interplant freight cost, and improve inventory accuracy with some of the supply chain technology we have implemented."

Thus, though supply chain technology has not provided the expected benefits for many of the responding firms, a minority of firms have had their expectations exceeded.

5.2 Correlation Analysis

After examining the technology adoption patterns and benefits of responding firms, correlation analysis was performed to investigate relationships between a large set of potential independent variables and technology adoption.

The survey included several measures of technology adoption (Appendix 1). Initially, four measures of technology adoption were analyzed with a small sample of independent variables to compare the results using different technology measures. These measures include the number and degree of functional technologies adopted (Question 12), number and degree of integrative technologies adopted (Question 16), the extent of adoption within each functional area (Question 13), and the extent of automation by functional area (Question 14). Correlation analysis using the four measures indicated much overlap and similarity. To simplify the results and avoid redundancy, two measures

of technology adoption were selected for inclusion in the correlation analysis: degree of technologies adopted (Question 12) and extent of functional area adoption (Question 13). The two measures were selected because they provide a more direct and complete measure of adoption than the two excluded questions and also provide a diverse and richer examination of the research questions.

The first measure was an average technology score computed by summing the responses across the 13 functional technologies (Question 12) and dividing by the total number. Since the response "Not At All" was scored a 1 on the web-enabled survey, responses of NA or no answer were also scored a 1. Thus, the technology adoption score ranged from 1 to 5. The second measure of technology adoption used in the correlation analyses was a measure of functional area adoption (Question 13). This was computed as just stated except that there were eight functional areas in the survey and thus the denominator was eight.

The independent variables included a variety of organizational and environmental variables frequently represented by several questions. The independent variables included organizational size, organizational structure, supply chain management strategy integration, firm performance, environmental uncertainty, and supply chain relationships.

Table 29 contains the correlations between organizational size, organizational structure and strategy integration with technology adoption. Size, as measured by total revenue, significantly correlates with technologies adopted but not with functional area adoption. This suggests that the greater the revenue, the greater the number of technologies adopted. However the analyses does not indicate the same relationship when using number of employees as a measure of firm size.

The next variable examined was organizational structure as measured by three survey questions: decentralized decision making (reverse coded in the survey), use of cross functional teams, and reduced organizational structure to integrate operations. Theory and some previous research suggests firms with a more decentralized organizational structure would be more likely to have adopted greater levels of technology (Grover and Goslar, 1993). The results indicate a positive and significant relationship between decentralized decision-making and technologies adopted, and a similar relationship between use of cross-functional teams and functional area adoption. Reduced formal organizational structure is positively associated with both measures of technology adoption. Thus, the direction of the relationship is as expected.

A well-coordinated and integrated supply chain management strategy has also been suggested to positively relate to the adoption of supply chain technologies. The significant and positive relationships between all three strategy questions with both measures of adoption provide strong support for this assertion.

Table 30 presents the correlations between technology adoption and a firm's budget for technology, number of technology employees, and a variety of measures of firm performance. The annual budget for supply chain technology was positively correlated with the number of technologies adopted but not with functional area adoption. However the number of supply chain technology employees was not significantly related. The data suggests that most companies have very few employees dedicated to supply chain technologies and written responses suggest most firms use technology vendors to implement many of these technologies. Thus, it appears that most firms may outsource

the implementation, training, and maintenance of these technologies and thus have very few information technology employees.

Several measures of firm performance are also positively and significantly related to supply chain technology adoption (Table 30). The respondents were asked to indicate their firm's level of performance in comparison to major industry competitors. Many of the measures of current firm performance (i.e. market share, return on total assets, customer service levels, product quality, competitive position) are significantly and positively related to both measures of technology adoption. Thus, these findings suggest currently successful firms have adopted greater levels of technology. Additionally, past performance, as measured by market share growth, sales growth, and growth in ROA over the past three years all related positively to one or the other measure of adoption. It was expected that past performance would be negatively correlated with adoption as successful firms would be less likely to adopt new technologies and strategies because of the tendency towards "strategic persistence" of successful firms (Audia et al., 2000). These findings suggest more successful firms during the previous three years have adopted more technology and thus contradict expected relationships.

The next set of questions dealt with the level of environmental uncertainty, supply chain complexity, supply chain partner adoption tendencies, and supplier characteristics. It was believed that uncertainty would encourage firms to adopt technologies in order to improve information exchange, which in turn would lead to greater responsiveness, flexibility and competitiveness. Thus, a positive relationship was expected. Surprisingly, none of the three measures of uncertainty were significantly related to either adoption measure (Table 31). Complexity of supply chain operations, which encompasses number

of customers/sellers, geographical dispersion, delivery timing requirements, etc., did correlate positively to the number of technologies adopted. While it was thought that firms in supply chains with partners that were technologically advanced would also have adopted more technologies because of partner influence, this was generally found not to be the case. The results indicate that only customer adoption patterns relate significantly and positively to number of technologies adopted while carrier adoption patterns relate to functional area adoption measures. This finding was also supported by individual written comments on the survey as many stated that their company had adopted new technologies because customers were requiring the technologies or were "demanding better service and lower costs." Supplier characteristics appear to be unrelated to technology adoption patterns in the responding firms.

Table 32 reports the relationships between the size of the firm's supply network and electronic commerce practices with supply chain technology adoption. Interestingly, the number of customers and suppliers was related less to technology adoption than the number of carriers and third party logistics providers (Table 32). It appears that highly adopting firms have a larger network of carriers and 3PLP than customers and suppliers.

The percentage of customers and suppliers with which firms conducted computer-based business transactions (i.e. electronic commerce) and the related variable - percentage of documents transmitted using technology - were all positively and significantly related to both measures of supply chain technology adoption (Table 32). These findings indicate that firms that have adopted these technologies are indeed using them to replace the old manual systems and processes.

The final question focused on supply chain partner relationships. It was hypothesized that higher levels of commitment and trust between partners would lead to more adoption which in turn would lead to greater cooperation and information exchange. This question also examined the impact of partner pressure on adoption patterns. The results (Table 33) suggest that relationship characteristics with suppliers and carriers are more important to adoption than relationships with customers and 3PLP. Commitment to partners was consistently positively and significantly correlated to both adoption measures. Trust in suppliers was important to both adoption measures while trust in customers did not significantly relate to either measure and trust in carriers and 3PLP related to functional area adoption. It appears that commitment to all partners is important for technology adoption while trust in suppliers is more important than trust in customers.

Satisfaction with cooperation and information exchange with customers, suppliers and carriers was generally positively related with adoption patterns (Table 33). Interestingly, customer encouragement to adopt technologies was significantly related to both measures of adoption while supplier encouragement was only related to the number of technologies adopted. As mentioned previously, this agrees with many comments from the survey. When responding to an open-ended question concerning environmental factors impacting adoption of supply chain technology, many of the responses included satisfying customer requirements as a motivation for supply chain technology adoption. One final interesting finding was that switching suppliers was negatively and significantly related to the number of technologies adopted. Relatedly, supplier commitment, trust,

cooperation and information exchange were also positively associated with technology adoption.

To summarize, correlation analysis indicates significant relationships between many of the variables included in the survey and technology adoption. Organizational size, decentralization, and corporate integration of supply chain strategy relate to technology adoption. Furthermore, trust and commitment between partners is positively associated with technology adoption while customer and supplier encouragement also positively correlates with technology adoption. Two findings that contradict expectations suggest past performance relates positively with technology adoption and environmental uncertainty does not factor into the adoption process.

Table 29: Correlations (Size, Structure, Strategy Integration)

	Technologies Adopted	Functional Area Adoption
Employees	.187 (.058)	.078 (.436)
Revenues	.243* (.015)	.180 (.073)
Concentrated decision making at top Man. levels	.266** (.007)	.183 (.065)
Clear and comprehensive SCM strategy	.366** (.000)	.398** (.000)
Extensive use of cross-functional teams	.154 (.121)	.239 (.015)
Reduced formal organizational structure to integrate ops	.194* (.050)	.240* (.015)
SCM planning coordinated with overall strategic planning	.407** (.000)	.455** (.000)
SCM strategy incorporated with overall business strategy	.401** (.000)	.447** (.000)

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

Table 30: Correlations (Technology Budget, Employees, Performance)

	Technologies Adopted	Functional Area Adoption
Annual budget for SC technology	.312** (.008)	.165 (.165)
No. of tech employees dedicated to SCT	.144 (.185)	.151 (.165)
Market Share	.410** (.000)	.273** (.006)
Return on Total Assets	.421** (.000)	.232* (.019)
Market Share Growth (over past 3 years)	.189 (.055)	.210* (.033)
Sales Growth (over past 3 years)	.188 (.059)	.201* (.044)
Growth in ROA (over past 3 years)	.329** (.001)	.156 (.118)
Average Production Costs	-.097 (.352)	.040 (.700)
Overall Customer Service Levels	.263** (.008)	.241* (.015)
Overall Product Quality	.315** (.001)	.272** (.006)
Overall Competitive Position	.412** (.000)	.414** (.000)
Overall Cost To Serve	.078 (.439)	.193 (.053)

Table 31: Correlations (Uncertainty, complexity and partner technology adoption)

	Technologies Adopted	Functional Area Adoption
Intense competitive environment for firm's products & services	.024 (.805)	.005 (.956)
Complex supply chain	.192* (.047)	.178 (.066)
Stable demand for goods & services	-.038 (.698)	.022 (.821)
Company change and uncertainty	.184 (.057)	.077 (.428)
Industry change and uncertainty	.030 (.757)	-.106 (.277)
Customers quickly adopt new technologies	.260** (.007)	.130 (.184)
Suppliers quickly adopt new technologies	.086 (.379)	.068 (.486)
Carriers quickly adopt new technologies	.140 (.153)	.213* (.029)
3PLPs quickly adopt new technologies	.078 (.465)	.174 (.101)
Stable number of suppliers	-.125 (.200)	-.048 (.621)
Consistent percentage of certified suppliers	-.096 (.339)	.065 (.520)
Stable supply of components from suppliers	-.120 (.240)	-.013 (.897)
Consistent quality of components from suppliers	.069 (.502)	.060 (.559)

Table 32: Correlations (Number of Partners and Electronic Commerce)

	Technologies Adopted	Functional Area Adoption
Total number of customers	.049 (.619)	.069 (.484)
Number of strategic customers	.003 (.981)	.121 (.244)
Total number of suppliers	.162 (.105)	.116 (.247)
Number of strategic suppliers	.232* (.025)	.198 (.057)
Total number of carriers	.267** (.007)	.233* (.019)
Number of strategic carriers	.120 (.244)	.131 (.202)
Total number of 3PLPs	.211* (.047)	.223* (.035)
Number of strategic 3PLPs	.115 (.290)	.287** (.007)

	Technologies Adopted	Functional Area Adoption
Percentage of customers w/ whom your firm conducts EC	.360** (.000)	.265** (.010)
Percentage of suppliers w/ whom your firm conducts EC	.273** (.008)	.231* (.026)
Percentage of documents transmitted via technology	.321** (.002)	.311** (.002)

Table 33: Correlations (Relationship with customers, suppliers, carriers, 3PLP)

	Technologies Adopted	Functional Area Adoption
Strong commitment with customers	.506** (.000)	.429** (.000)
Customers can be trusted	.134 (.192)	.126 (.218)
Satisfied with cooperation with customers	.321** (.001)	.325** (.001)
Satisfactory information exchange with Customers	.179 (.082)	.312** (.002)
Firm has encouraged customers to adopt technology	.182 (.091)	.170 (.116)
Customers have encouraged firm to adopt technology	.287** (.007)	.253* (.018)
Company switches customers more often than before	-.053 (.612)	-.079 (.450)
Company maintains longer relationships with customers	.103 (.333)	-.067 (.526)

	Technologies Adopted	Functional Area Adoption
Strong commitment with suppliers	.361** (.000)	.406** (.000)
Suppliers can be trusted	.235* (.019)	.355** (.000)
Satisfied with cooperation with suppliers	.183 (.068)	.300** (.002)
Satisfied with information exchange with suppliers	.213* (.033)	.275** (.006)
Firm has encouraged suppliers to adopt technology	.346** (.001)	.260* (.014)
Suppliers have encouraged firm to adopt technology	.293** (.005)	.163 (.128)
Company switches suppliers more often than before	-.263** (.009)	-.129 (.209)
Company maintains longer relationships with suppliers	.055 (.600)	.098 (.343)

Table 33 continued

	Technologies Adopted	Functional Area Adoption
Strong commitment with carriers	.273** (.008)	.424** (.000)
Carriers can be trusted	.130 (.213)	.343** (.001)
Satisfied with cooperation with Carriers	.294** (.004)	.412** (.000)
Satisfied with information exchange with carriers	.273** (.008)	.428** (.000)
Carriers have encouraged firm to adopt technology	.208 (.056)	.188 (.085)
Firm has encouraged carriers to adopt technology	.268* (.014)	.223* (.042)
Company switches carriers more often than before	-.115 (.285)	-.048 (.653)
Company maintains longer relationships with carriers	.204 (.061)	.240* (.027)

	Technologies Adopted	Functional Area Adoption
Strong Commitment with 3PLP	.248 (.065)	.343** (.010)
3PLP can be trusted	.167 (.222)	.350** (.009)
Satisfied with cooperation with 3PLP	.166 (.226)	.246 (.070)
Satisfied with information exchange with 3PLP	.072 (.600)	.204 (.135)
Firm has encouraged 3PLP to adopt technology	.259 (.061)	.176 (.207)
3PLPs have encouraged firm to adopt technology	.117 (.414)	-.038 (.793)
Company switches 3PLP more often than before	-.207 (.142)	-.163 (.249)
Company maintains longer relationships with 3PLP	.157 (.265)	.192 (.174)

5.3 Model Testing

Following the correlation analysis, regression analysis was used to examine the impact of each of the seven variables in the proposed model (See Figure 1) on supply chain technology adoption. The two measures of adoption previously discussed were used as dependent variables in separate regression models. This section discusses the variables used in the analysis and the influence of the independent variables on technology adoption.

5.3.1 Operationalization of Constructs

The survey contained several questions potentially applicable to each construct. This section discusses the selection of each question chosen to represent the variables included in the model (Figure 1).

The same two measures of technology adoption used to examine correlations were also used in the regression analysis: degree of technologies adopted and extent of functional area adoption. As previously mentioned, both adoption measures were computed by averaging the responses to the 13 technology questions and eight functional area questions, respectively (See Correlation Section for more discussion of dependent variables).

The survey also included several potential questions regarding each independent variable of the model. Correlation analysis of these potential variables was conducted to examine collinearity between questions (Table 34). The results indicate high correlation between employee number and revenue, coordinated strategy planning and incorporated

Table 34: Correlation Matrix of Potential Independent Variables

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. Employee No.	-															
2. Revenue No.	.783**	-														
3. Decentralized Decision-making	.151	.199*	-													
4. Reduced Org. Structure	-.142	-.080	-.077	-												
5. Cross functional teams	-.042	.089	.135	.512**	-											
6. Comprehensive SCM Strategy	-.042	-.083	-.004	.456**	.361**	-										
7. Coordinated SCM Planning	-.039	-.024	.033	.459**	.426**	.606**	-									
8. Incorporated SCM Strategy	-.105	.013	.029	.420**	.410**	.716**	.795**	-								
9. Market share growth	.164	.172	.083	.246*	.277**	.234*	.261**	.251*	-							
10. Sales growth	.164	.176	-.001	.349**	.384**	.386**	.378**	.405**	.713**	-						
11. ROA growth	.154	.175	-.021	.365**	.371**	.333**	.289**	.301**	.536**	.694**	-					
12. Transaction Climate	.035	.218*	.092	.143	.085	.120	.225*	.203*	.181	.203*	.175	-				
13. SC Partner Pressure	-.037	.117	.077	.249*	.179	.228*	.254**	.257**	.223*	.274**	.247*	.706**	-			
14. Stable demand	-.040	-.045	-.061	.006	-.054	-.059	.004	-.050	.279**	.231*	.183	.043	.050	-		
15. Company unc.	.016	-.003	.129	.035	-.075	.107	.046	.026	.299**	.291**	.209*	-.034	.013	.402**	-	
16. Industry unc.	.057	-.002	.206*	.123	.100	.011	.011	.029	-.177	-.229*	-.086	-.101	-.099	.409**	.623**	-

supply chain management strategy, market share growth and sales growth, and transaction climate and supply chain member pressure.

The questions selected for inclusion in the model estimation were those believed to be the best indicators of each construct being examined. After careful consideration of question content, the following measures were determined to be most logical and appropriate for the regression analyses:

Construct	Measure
1. Organizational Size	Number of employees
2. Organizational Structure	Question 1a (reverse coded): Degree of decentralized decision-making
3. Organizational Performance	Question 4e: Past performance as measured by ROA growth over the past three years
4. Supply Chain Strategy Integration	Question 1f: Degree of supply chain strategy incorporation into overall business strategy
5. Transaction Climate	Average of Questions 11a, 11b, 11i, 11j, 11q, 11r, 11y, 11z: Extent of trust and commitment between the responding firm and supply chain partners
6. Supply Chain Member Pressure	Average of Questions 11f, 11n, 11u, 11dd: Extent of "encouragement" from supply chain partners
7. Environmental Uncertainty	Question 5d: Degree of change and uncertainty faced by the company

Two of the independent variables (transaction climate and supply chain member pressure) were derived by averaging responses across a number of related questions. The "transaction climate" variable was a composite value calculated by averaging the extent of trust and commitment between the respondent's firm and its suppliers, customers,

carriers, and third party logistics providers. The "supply chain member pressure" variable was computed by averaging the degree to which customers, suppliers, carriers, and third party logistics providers had encouraged the respondent's firm to adopt supply chain technology. Tables 35 and 36 report the correlations between the components of these two measures. Significant correlations are widespread among the components of both measures.

Next, the seven selected independent variables were evaluated for potential collinearity using correlation analysis. Table 37 presents the correlation matrix for the independent variables used in the two regression analyses. The highest degree of correlation between independent variables is between transaction climate and supply chain partner pressure with a Pearson's Correlation Coefficient of .706 and a significance level of .01. This level of correlation may indicate collinearity problems between these two constructs in the regression analysis.

One of the more common methods of assessing multicollinearity is through the use of the Variance Inflation Factor (VIF) (Hair et al., 1998). The VIF indicates the degree to which the selected independent variable is affected by or explained by the other independent variables. According to authors, a common VIF threshold used in many statistical packages is 10 (Hair et al., 1998). Table 37 reports the VIF for each of the seven selected independent variables. The supply chain partner pressure variable contains the highest VIF value of 2.094 which is well within the common cutoff. Thus, collinearity, while present, may not be a major problem.

Table 35: Correlations Between Transaction Climate Components

	1	2	3	4	5	6	7	8
1. Commitment with customers	-							
2. Trust in customers	.445**	-						
3. Commitment with suppliers	.335**	.164	-					
4. Trust in suppliers	.311**	.451**	.602**	-				
5. Commitment with carriers	.332**	.295**	.253*	.232*	-			
6. Trust in carriers	.387**	.362**	.171	.313**	.620**	-		
7. Commitment with 3PLP	.196	.176	.253	.274*	.160	.247	-	
8. Trust in 3PLP	.241	.301*	.435**	.298*	.149	.412**	.714**	-

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 36: Correlations Between Supply Chain Partner Pressure Components

	1	2	3	4
1. Customer Encouragement	-			
2. Supplier Encouragement	.442**	-		
3. Carrier Encouragement	.342**	.474**	-	
4. 3PLP Encouragement	.275	.373**	.459**	-

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 37: Correlation Matrix for Independent Variables

	1	2	3	4	5	6	7	VIF
1. Employee Number	-							1.088
2. Decentralization	.151	-						1.048
3. Past Performance	.154	-.021	-					1.279
4. Strategy Integration	-.105	.029	.301**	-				1.180
5. SC Partner Pressure	-.037	.077	.247*	.257**	-			2.094
6. Transaction Climate	.035	.092	.175	.203*	.706**	-		1.992
7. Environmental Uncertainty	.016	.129	-.209*	.026	-.034	.013	-	1.090

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed).

5.3.2 Impact on Technology Adoption

The first regression analysis used the average adoption score of the 13 functional technologies as the measure of technology adoption to determine the impact of the seven independent variables (Table 38). The overall model was significant at the .01 level with almost 42% of the variance associated with technology adoption explained by the seven variables. Five of the seven variables were significant at the .05 alpha level while employee number was significant at the .1 level. The only variable that had insignificant explanatory power was transaction climate. Furthermore, the direction of the relationships were as expected for six of the seven variables. The only unexpected direction involved past organizational performance. Thus, five of the seven hypotheses relating to factors impacting adoption were supported in this study.

Table 39 presents the model estimation results using functional area adoption as the dependent variable. The overall model is significant at the .01 level and the seven independent variables explain 30% of the variation in the dependent variable. However, only one of the variables is a significant predictor of functional area adoption: the degree of supply chain strategy integration. Thus, only Hypothesis 4b was supported using functional area adoption as the measure of supply chain technology adoption.

A detailed discussion of the variables and hypotheses are presented in the sections below.

Table 38: Summary of Model 1 Regression Analysis

Independent Variable	Standardized Coefficients	Significance
Employee Number	.161	.054
Decentralization	.190	.022
Past Performance	.200	.028
Strategy Integration	.268	.003
SC Partner Pressure	.252	.031
Transaction Climate	.047	.677
Environmental Uncertainty	.200	.018
Overall Model		.000
$R^2 = .419$		
No. of observations = 100		

Dependent Variable: Technologies Adopted

Table 39: Summary of Model 2 Regression Analysis

Independent Variable	Standardized Coefficients	Significance
Employee Number	.116	.203
Decentralization	.137	.127
Past Performance	-.016	.867
Strategy Integration	.385	.000
SC Partner Pressure	.121	.338
Transaction Climate	.147	.234
Environmental Uncertainty	.075	.411
Overall Model		.000
$R^2 = .304$		
No. of observations = 100		

Dependent Variable: Functional Area Adoption

Organizational Variables

H1: The larger the organization, the more likely it will be to adopt supply chain technology as measured by (a) technologies adopted and (b) functional area adoption.

The first organizational variable examined was organizational size. Organizational size, as measured by the number of employees, was positive and significant at the .10 level (Table 38) in model 1; thereby supporting Hypothesis 1a. These results suggest as the number of employees increase, the extent of adoption of the 13 supply chain technologies also increases. As theorized, it appears that firms with greater numbers of employees adopt more technologies perhaps to improve information management and activity coordination. However, size was not significant in Model 2. This suggests that size does not influence the degree to which functional areas have adopted appropriate technologies. Thus, Hypothesis 1b was not supported.

H2: The more decentralized the organization, the more likely it will be to adopt supply chain technology as measured by (a) technologies adopted and (b) functional area adoption.

Decentralization, the second organizational variable of the study, also appears to lead to greater technology adoption. The variable was positive and significant at the .05 level, suggesting that one can be 95% sure that firms that have less concentrated decision-making routines adopt more technologies. Thus, Hypothesis 2a is supported. These results support Grover and Goslar (1993) who suggested that a more decentralized

organizational structure leads to greater boundary scanning, greater awareness of business opportunities, and thus greater levels of technology adoption.

The organizational variable in model 2 is not significant. As a result, Hypothesis 2b is not supported, and suggests that organizational structure does not impact technology adoption throughout functional areas.

H3: Less successful organizations in the past will be more likely to adopt supply chain technology as measured by (a) technologies adopted and (b) functional area adoption.

Results indicate past performance significantly impacts technology adoption, however the direction of the relationship is opposite of what was proposed (Table 38). Thus, Hypothesis 3a is rejected. Previous research (Feitler et al., 1998; Audia et al., 2000) suggests that better performing firms have a tendency of strategic persistence and adopt fewer strategic changes than poorer performing firms. Considering information management systems have become essential components of firm strategy, it was therefore expected that poorer performing firms would be more likely to adopt new technology. However, this data indicates that past performance is positively associated with technology adoption. This is an interesting finding as it suggests that better performing firms over the past three years, in comparison to major competitors, adopt more technologies. As Table 13 indicates, most functional areas have adopted important technologies during the past three years. Thus, the timing of adoption and performance seems to suggest that firms that are performing better adopt more technologies.

Using functional area adoption as the dependent variable (model 2), past performance is not significant but has a negative coefficient. It appears that past performance may be negatively related to functional area adoption, but not significantly. Though Hypothesis 3b is also rejected in model 2, the direction is as hypothesized.

H4: Organizations that have integrated supply chain management strategy with overall corporate strategy will be more likely to adopt supply chain technology as measured by (a) technologies adopted and (b) functional area adoption.

The final organizational variable included in the model was supply chain strategy integration. The degree to which supply chain management strategy is incorporated into overall business strategy appears to be another driver of supply chain technology adoption. This variable, significant at the .01 level, supports Hypothesis 4a and suggests that one can be 99% sure that supply chain strategy incorporation positively influences supply chain technology adoption. As Bowersox and Daugherty (1995) suggested, as firms realize the advantages gained from efficient and effective supply chain operations, managers begin to incorporate supply chain strategy into their overall corporate strategy which then leads to greater technology adoption and electronic integration.

The results indicate the degree of supply chain strategy integration also significantly and positively influences functional area adoption at the .01 level, and provide support for Hypothesis 4b. This should come as no surprise as those firms with a more integrated supply chain strategy would also probably tend to have a more integrative approach to technology adoption resulting in more comprehensive adoption activities

Environmental Variables

In addition to organizational variables, three environmental variables were also included in the regression analysis. Those three variables include transaction climate with supply chain partners, supply chain partner pressure and environmental uncertainty. The results in Table 38 for model 1 provide support for Hypotheses 5a and 7a and indicate both supply chain partner pressure and environmental uncertainty are significant predictors of adoption of the thirteen supply chain technologies. With respect to functional area adoption, no environmental constructs appear to impact this adoption measure.

H5: Organizations subjected to greater supply chain partner pressure will be more likely to adopt supply chain technology as measured by (a) technologies adopted and (b) functional area adoption.

The first environmental variable examined was supply chain partner pressure. This variable was positive and significant in model 1 (Table 38) and provides support for Hypothesis 5a. The results suggest supply chain partners successfully pressure organizations to adopt new technologies. Conversely, supply chain partner pressure was not significant when functional area adoption was the dependent variable (Table 39), and thus, Hypothesis 5b was not supported.

H6: Organizations with a more favorable transaction climate with supply chain members will be more likely to adopt supply chain technology as measured by (a) technologies adopted and (b) functional area adoption.

Transaction climate represents the trust and commitment between the responding firm and its supply chain partners. It was hypothesized that a positive transaction climate would lead to greater technology adoption, as constructive relationships with supply chain partners would encourage firms to invest in equipment and technology. The variable was positive but insignificant in both regression models. Consequently, Hypotheses 6a and 6b were not supported in either model.

H7: Organizations facing higher environmental uncertainty will be more likely to adopt supply chain technology as measured by (a) technologies adopted and (b) functional area adoption.

Environmental uncertainty was measured as the extent of change and uncertainty faced by the company. It was hypothesized that greater environmental uncertainty would lead to greater technology adoption as uncertainty creates the need for more accurate information in order to respond as environmental conditions necessitate (Ahmad and Schroder, 2001). As expected, results indicate firms facing greater uncertainty adopt more supply chain technologies; thereby supporting Hypothesis 7a. However, it does not appear that uncertainty affects the extent of functional area adoption. This variable in

model 2 was not significant and does not provide support for Hypothesis 7b when using functional area adoption as the dependent variable.

5.3.3 Technology Adoption and Organizational Benefits

In the research model, it was also hypothesized that organizations would achieve improvements in supply chain integration and logistics performance measures from the adoption of supply chain technologies. In order to test these hypotheses, correlation analysis was performed to examine the relationship between technology adoption and organizational benefits (Table 40). Questions 21a-21q and Question 22 measured the benefits attained by the responding firms and were used in the analysis with the two previously mentioned measures of supply chain technology adoption: technologies adopted and functional area adoption.

H8: Adopting organizations, as measured by (a) technologies adopted and (b) functional area adoption, will be more likely to have achieved higher levels of logistics performance improvements.

Table 40 indicates correlations significant at the .01 level for most of the logistics performance improvements with both measures of adoption. These findings provide support for Hypotheses 8a and 8b.

H9: Adopting organizations, as measured by (a) technologies adopted and (b) functional area adoption, will be more likely to have achieved higher levels of supply chain integration improvements.

Table 40 also indicates significant and positive correlations between adoption and two measures of supply chain integration: information sharing and coordination of logistics activities with suppliers and customers. These findings support Hypotheses 9a and 9b and previous research (Stank et al., 1999).

In conclusion, the data supports 10 of the 18 hypothesized relationships and indicate firm size, a decentralized organizational structure, supply chain strategy integration, supply chain partner pressure, and environmental uncertainty do impact supply chain technology adoption as measured by the adoption of functional technologies (See Table 41 for Summary of Hypotheses Tested). Furthermore, adoption of supply chain technologies leads to significant improvements in many fundamental logistics performance measures and integration of the supply chain.

Table 40: Correlations of Supply Chain Benefits with Technology Adoption Measures

	Technologies Adopted	Functional Area Adoption
Reduced cost of placing orders with supplier	.139 (.201)	.291** (.006)
Reduced cost of processing customer orders	.168 (.109)	.309** (.003)
Reduced inventory levels	.271* (.013)	.284** (.009)
Improved inventory turnover	.153 (.171)	.185 (.095)
Improved shipment accuracy	.218* (.039)	.316** (.002)
Reduced lead time	.277** (.008)	.378** (.000)
Improved customer service	.306** (.003)	.351** (.001)
Increased customer satisfaction	.275** (.007)	.356** (.000)
Provides better understanding of cost to serve	.277** (.008)	.391** (.000)
Improved product to market speed	.264* (.018)	.409** (.000)
Improved on-time delivery from suppliers	.272* (.011)	.279** (.009)
Provides better distinction of types of inventory	.246* (.047)	.324** (.008)
Improved information sharing with suppliers and customers	.299** (.004)	.297** (.004)
Improved coordination of logistics activities with suppliers and customers	.340** (.001)	.407** (.000)
Increased trust in suppliers and customers	.061 (.566)	.156 (.137)
Increased commitment to supply chain relationships	.068 (.521)	.075 (.479)
Positive impact on performance of entire supply chain	.343** (.001)	.429** (.000)

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 41: Summary of Hypotheses Tested

Hypothesis	Technologies Adopted (a)	Functional Area Adoption (b)
H1: Organizational Size	Supported	Unsupported
H2: Decentralized Organizational Structure	Supported	Unsupported
H3: Past Organizational Performance	Unsupported	Unsupported
H4: Supply Chain Strategy Integration	Supported	Supported
H5: Transaction Climate	Unsupported	Unsupported
H6: Supply Chain Partner Pressure	Supported	Unsupported
H7: Environmental Uncertainty	Supported	Unsupported
H8: Logistics Performance Improvements	Supported	Supported
H9: Supply Chain Integration Improvements	Supported	Supported

6. CONCLUSIONS AND IMPLICATIONS

Integration of supply chain activities and the technologies to accomplish it have become competitive necessities in most industries. For example, one respondent to the survey wrote, "Our senior management have now come to realize that supply chain management will enhance our ability to be successful." Another commented, "With almost daily technology advancement globally in ever facet of the business, organizations need to synchronize by adopting and implementing new electronic commerce and supply chain technology in order to protect market share, not to mention improve market penetration." The primary objectives of this dissertation is to increase our understanding of the current state of supply chain technology employment, the factors impacting adoption, and the benefits of adoption. To this end, 15 of the most important supply chain technologies and several key organizational and environmental variables were identified and included in this study. Predictions of the influence of these variables on adoption were developed and empirically investigated.

In this chapter, an overall conclusion of the results of the previous chapter will be presented. Managerial implications, limitations and future research will also be discussed.

6.1 Conclusion

The survey data gathered in this exploratory study provide important insight into the current state of supply chain technology. Most of the responding firms are still largely adopting internally focused or functional technologies such as warehouse management systems while a small percentage of firms have begun electronically integrating activities throughout the supply chain with technologies such as supply chain planning systems and enterprise resource planning systems. Furthermore, most of the technologies have not been substantially adopted by the majority of firms. Finally, benefits have been achieved but appear to lag adoption rates.

The results also provide important understanding of key factors leading to adoption of supply chain technology. The first construct examined and found to be a significant predictor of technology adoption was firm size. Larger firms are more likely to have adopted these technologies than smaller firms. Large organizations may have greater volumes of transactions, more geographically dispersed operations, more supply chain partners, and/or more information to manage and thus are more likely to adopt information technology systems to improve operational efficiency and very often lower cost.

A decentralized organizational structure was also found to lead to adoption of the technologies examined in the study. This variable has been a point of contention in many studies as researchers have found both positive and negative relationships between decentralization and technology adoption. It appears that firms that allow decision-making to be located throughout the organization may engage in more environmental scanning, which leads to a greater awareness and appreciation of potential innovations.

Another important driver of supply chain technology adoption is the integration of a firm's supply chain strategy with overall corporate strategy. This was the only antecedent that was significant with both measures of technology adoption. Organizations that understand the competitive benefits of efficient and effective supply chain operations incorporate supply chain strategy into organizational strategy. The elevation in importance of the supply chain in an organization then leads to the application of information technology to these operations.

Supply chain partner pressure is another important predictor of the adoption of supply chain technology. As previously reported (Bouchard, 1993; Truman, 2000) supply chain partners have a substantial impact on a firm's decision to adopt supply chain technologies. As organizations integrate operations and technology becomes more prevalent, firms are coercing members of their supply chain to adopt new technologies to satisfy the need for fast and accurate information. From the many written comments on the survey, it appears that customers exert greater pressure than other partners in the supply chain. A typical comment was, "Most customers demand this technology or they will go someplace else."

The final construct found to drive adoption was environmental uncertainty. Organizations facing greater uncertainty employ supply chain technology to improve information management and exchange in order to be able to better respond to changing environmental conditions. As Kwan (1999) suggested, information technologies allow firms to more quickly and accurately share demand data, sales projections and production schedules which provides adopting organizations greater flexibility and responsiveness in the face of a constantly changing environment.

With respect to benefits of supply chain technology adoption, organizations report significant relationships between adoption and improvements in both logistics performance measures and supply chain integration. Adoption leads to reduced inventory levels, improvements in shipping accuracy, and improved customer service and satisfaction to name just a few. Additionally, supply chain technology improves integration by increasing information sharing and coordination of logistics activities with suppliers and customers. Firms also report improvement in the performance of the entire supply chain due to supply chain technology adoption as well.

6.2 Managerial Implications

The results of this study provide several important managerial implications. First is the understanding of the current state of supply chain technology. Supply chain managers can use this information to compare their organization's use of technology with the group of respondents in the survey. These results may stimulate discussion within organizations of which technologies may be appropriate for consideration of adoption. A second contribution is the conclusion that supply chain strategy integration leads to adoption of these technologies. If supply chain managers can elevate the status of logistics operations within the organization, top management will likely begin recognizing the important competitive contributions these technologies afford and begin adopting them. A third important insight gained from this study is that these technologies often lead to improvements in many typical logistics measures as well as improvements in information sharing and coordination with supply chain partners. As more

organizations integrate supply chain operations, these results can be used to encourage decision makers to adopt supply chain technologies.

6.3 Limitations and Future Research

Like all research, this study has a number of limitations. First, as mentioned previously, is the use of perceptual data gathered via surveys. While it has been suggested that senior managers are reliable sources of knowledge of organizational technology adoption (DeLone and McLean, 1992) and their perceptions adequately correspond with objective performance measures (Venkatraman and Ramanujam, 1987), reporting errors may arise due to a variety of personal or positional characteristics such as the respondent's job satisfaction, tenure or lack of awareness of detailed operations throughout the organization (Bagozzi et al., 1991). Another area of concern is the use of cross sectional data to examine the direction of the relationships. A longitudinal study would provide a clearer understanding of the antecedents and effects of technology adoption. However, with the time limit imposed on the study, a longitudinal study was infeasible. The use of the general term "adoption" to encompass the various stages of technology generation and employment may be seen as a shortcoming as well. The various stages of adoption have been previously defined and could be used in a future study. An additional limitation was the measure of past performance used to test Hypothesis 4. Respondents were asked to evaluate their firm's performance over the past three years. Considering that most of the technologies have also been adopted within the past three years, the measure of performance probably coincides with adoption instead of

preceding it. This limitation may explain the unexpected findings relating to Hypothesis 4 and the rejection of it. Another issue may be the low response rate of almost 2%. A larger sample size would be more representative of the population and might allow for more generalizability. Another issue may be the use of single scale items to represent many of the constructs of the model. The use of multiple scale items and factor analysis would allow for tests of convergent and discriminant validity and allow for multiple facets of these constructs to be measured.

This exploratory study is the first extensive investigation of many of these recently developed supply chain technologies. As such, it provides an initial starting point from which to develop more detailed analyses of many of these constructs and information systems. For example, another study might explore potential interactions between independent variables or the presence of moderating variables that affect the benefits achieved by firms adopting supply chain technologies. Another investigation may attempt to increase the response rate to enhance generalizability of the results. A study focusing on manufacturing firms would also further the conclusions drawn in this examination. Another opportunity to expand this study would be to use multiple measures to represent many of the constructs. Multiple measures and a larger sample would enable the use of more sophisticated analysis methods such as structural equation modeling to provide additional insight into the relationships of the research model and facilitate a single analysis of the entire model. The results of this research could also lead to examination of individual technologies or subsets of these technologies such as the integrative technologies. A study focusing on individual technologies could indicate if technology type plays a role in the hypothesized relationships. An interesting study

would be to compare the technologies employed and benefits of integrated supply chains versus less integrated supply chains. Finally, a longitudinal study would allow for the examination of the impact of past performance on technology adoption.

APPENDIX

SUPPLY CHAIN INFORMATION TECHNOLOGY SURVEY

Part A: Organizational Characteristics and General Company Information

We believe that " best practice" information regarding supply chain technology would be very useful to supply chain managers and executives of companies. As such, we have compiled the following survey to assess which supply chain technology systems your company has adopted and implemented, as well as how the technology has been integrated within your organization. We will accumulate the responses to this survey and then will provide you with summary results, including information about best practices. The names of the respondents and their respective companies will be kept confidential and will not be shared with any third party organizations. A glossary of key terms is included at the end of the survey.

Company's name ____
Main line of business ____________________________________
Industry and SIC code (if available) ________________________
Your name, phone number and email address _________________
Your title ____
Your address ____

Please indicate the total number of employees in your company (all locations) by checking the appropriate line:

1_____ 100 or fewer
2_____ 101 - 500
3_____ 501 - 1000
4_____ 1,001 - 5000
5_____ 5,001or More

Please indicate the total revenues for your company (all locations) in 2000 by checking the appropriate line:

1_____ $100 million or less
2_____ MORE than $100 million, up to $500 million
3_____ MORE than $500 million, up to $1 billion
4_____ MORE than $1 billion, up to $2 billion
5_____ MORE than $2 billion

Please indicate the geographic scope of your company's operations? (Check one)

1_____ Regional
2_____ National
3_____ Worldwide

Please indicate the extent to which you agree with the survey statements by circling your responses using the following scale.

Not at All	Very Little	Somewhat	A significant Amount	To a Great Extent	No functional need for system
1	2	3	4	5	NA

1. Please indicate the extent to which you agree with the following statements.

a) Company decision-making is highly concentrated at top management levels 1 2 3 4 5

b) My company has a clearly stated and comprehensive supply chain management strategy 1 2 3 4 5

c) My firm extensively utilizes cross-functional work teams for managing day-to-day operations 1 2 3 4 5

d) My firm has reduced formal organizational structure to more fully integrate operations 1 2 3 4 5

e) In my company supply chain management planning is well coordinated with the overall strategic planning process 1 2 3 4 5

f) My company's supply chain management strategy us clearly incorporated into the organization's overall business strategy 1 2 3 4 5

2. What is the company's annual budget for operating/maintaining its supply chain technology? _______

3. How many information technology employees are dedicated to supply chain technology? _______

4. Please indicate the level of your firm's performance in the following measures compared to major industry competitors.

a) Market share 1 2 3 4 5

b) Return on total assets 1 2 3 4 5
c) Average annual market share growth (over the past three years) 1 2 3 4 5
d) Average annual sales growth (over the past three years) 1 2 3 4 5
e) Average annual growth in return on total assets (over the past three years) 1 2 3 4 5
f) Average production costs 1 2 3 4 5
g) Overall customer service levels 1 2 3 4 5
h) Overall product quality 1 2 3 4 5
i) Overall competitive position 1 2 3 4 5
j) Overall cost to serve 1 2 3 4 5

Part B: Environmental Factors

5. Please indicate the extent to which you agree with the following statements.

a) Compared to other industries, the competitive environment for my company's products and services is extremely intense 1 2 3 4 5
b) My firm's supply chain is extremely complex (number of customers/sellers, geographical dispersion, delivery timing requirements, etc.) 1 2 3 4 5
c) The demand for my company's goods and/services is stable 1 2 3 4 5
d) My company is facing much change and uncertainty 1 2 3 4 5
e) The industry in which my company participates is facing much change and uncertainty 1 2 3 4 5
f) My company's customers are generally quick to adopt new technology 1 2 3 4 5
g) My company's suppliers are generally quick to adopt new technology 1 2 3 4 5
h) My company's carriers are generally quick to adopt new technology 1 2 3 4 5
i) My company's 3rd Party Logistics Providers are generally quick to adopt new technology 1 2 3 4 5
j) The number of suppliers of my company has remained stable over the past 3 years 1 2 3 4 5
k) The percentage of certified suppliers for my company has remained consistent over the past 3 years 1 2 3 4 5
l) The supply of components from my firm's suppliers is stable 1 2 3 4 5
m) The quality of components from my firm's suppliers is consistent 1 2 3 4 5

6. Please comment on environmental factors that may have led your company to adopt and implement any new electronic commerce or supply chain technology.

____
____
____
____

Part C: Supply Chain Relationships

7. Please indicate the following:

a) Total number of customers < 100 100-500 501-1,000 >1,000

b) Number of strategic customers ________

c) Total number of suppliers < 100 100-500 501-1,000 >1,000

d) Number of strategic suppliers ________

e) Total number of carriers <10 10-50 51-100 >100

f) Number of strategic carriers ________

g) Total number of third party logistics providers ________

h) Number of strategic third party logistics providers ________

8. What is the percentage of customers with whom your firm conducts electronic commerce? ______ %

9. What is the percentage of suppliers with whom your firm conducts electronic commerce? ______ %

10. What percentage of all documents (including invoices, manifests, purchase orders, etc.) is transmitted to customers/suppliers/carriers via technology versus manual systems?

______ %

11. Please indicate the extent to which you agree with the following statements.

Customers

a) There is a strong commitment between my company and its customers 1 2 3 4 5 NA
b) My company's customers can be trusted to do what is right 1 2 3 4 5 NA
c) My company is generally satisfied with the level of cooperation between our firm and its customers 1 2 3 4 5 NA
d) My company is generally satisfied with the exchange of information between our firm and its customers 1 2 3 4 5 NA
e) My company's implementation of supply chain technology has encouraged customers to implement the technology 1 2 3 4 5 NA
f) Implementation of supply chain technology by my company's customers has encouraged my company to implement the technology 1 2 3 4 5 NA
g) My company switches customers more often than before 1 2 3 4 5 NA

h) My company's relationships with customers tend to last longer than before 1 2 3 4 5 NA

Suppliers

i) There is a strong commitment between my company and its suppliers 1 2 3 4 5 NA

j) My company's suppliers can be trusted to do what is right 1 2 3 4 5 NA

k) My company is generally satisfied with the level of cooperation between our firm and its suppliers 1 2 3 4 5 NA

l) My company is generally satisfied with the exchange of information between our firm and its suppliers 1 2 3 4 5 NA

m) My company's implementation of supply chain technology has encouraged suppliers to implement the technology 1 2 3 4 5 NA

n) Implementation of supply chain technology by my company's suppliers has encouraged my company to implement the technology 1 2 3 4 5 NA

o) My company switches suppliers more often than before 1 2 3 4 5 NA

p) My company's relationships with suppliers tend to last longer than before 1 2 3 4 5 NA

Carriers

q) There is a strong commitment between my company and its carriers 1 2 3 4 5 NA

r) My company's carriers can be trusted to do what is right 1 2 3 4 5 NA

s) My company is generally satisfied with the level of cooperation between our firm and its carriers 1 2 3 4 5 NA

t) My company is generally satisfied with the exchange of information between our firm and its carriers 1 2 3 4 5 NA

u) Implementation of supply chain technology by my company's carriers has encouraged my company to implement the technology 1 2 3 4 5 NA

v) My company's implementation of supply chain technology has encouraged its carriers to implement the technology 1 2 3 4 5 NA

w) My company switches carriers more often than before 1 2 3 4 5 NA

x) My company's relationships with carriers tend to last longer than before1 2 3 4 5 NA

3rd Party Logistics Providers (3PLP)

y) There is a strong commitment between my company and its 3PLP 1 2 3 4 5 NA

z) My company's 3PLP can be trusted to do what is right 1 2 3 4 5 NA

aa) My company is generally satisfied with the level of cooperation between our firm and its 3PLP 1 2 3 4 5 NA

bb) My company is generally satisfied with the exchange of information between our firm and its 3PLP 1 2 3 4 5 NA

cc) My company's implementation of supply chain technology has encouraged its 3PLP to implement the technology 1 2 3 4 5 NA

dd) Implementation of supply chain technology by my company's 3PLP has encouraged my company to implement the technology 1 2 3 4 5 NA

ee) My company switches 3PLP more often than before 1 2 3 4 5 NA

ff) My company's relationships with 3PLP tend to last longer than before 1 2 3 4 5 NA

Part D: Adoption of Supply Chain Information Technology

12. The following supply chain technology systems have been adopted and implemented.

a) Product Data Management (PDM)	1 2 3 4 5 NA
b) Customer Relationship Management (CRM)	1 2 3 4 5 NA
c) Automated Quality Control (AQC) system	1 2 3 4 5 NA
d) Computer Aided Design (CAD) systems	1 2 3 4 5 NA
e) Warehouse Management Systems (WMS)	1 2 3 4 5 NA
f) Manufacturing Execution Systems (MES)	1 2 3 4 5 NA
g) Transportation Management Systems (TMS)	1 2 3 4 5 NA
h) Radio Frequency (RF) systems	1 2 3 4 5 NA
i) Geo-coded Tracking systems	1 2 3 4 5 NA
j) Bar coding technology	1 2 3 4 5 NA
k) Electronic Commerce Technologies	1 2 3 4 5 NA
l) Supply Chain Event Management (SCE)	1 2 3 4 5 NA
m) Demand Forecasting Management	1 2 3 4 5 NA

13. The following organizational functions have adopted and implemented the appropriate information technology systems from the above list.

a) Accounting	1 2 3 4 5 NA
b) Transportation	1 2 3 4 5 NA
c) Warehousing	1 2 3 4 5 NA
d) Manufacturing/Operations	1 2 3 4 5 NA
e) Inventory Management	1 2 3 4 5 NA
f) Order Management	1 2 3 4 5 NA
g) Customer Service	1 2 3 4 5 NA
h) Research & Development	1 2 3 4 5 NA

14. To what extent has supply chain technology been incorporated (replacing manual transactions with automated processes) within the following functions:

0-20% 21-40% 41-60% 61-80% 81-100%

a) Accounting	1 2 3 4 5
b) Transportation	1 2 3 4 5
c) Warehousing	1 2 3 4 5
d) Manufacturing/Operations	1 2 3 4 5
e) Inventory Management	1 2 3 4 5

f) Order Management 1 2 3 4 5
g) Customer Service 1 2 3 4 5
h) Research & Development 1 2 3 4 5

15. The most significant supply chain technology hardware/software was implemented in the following functional areas:

	Not Implemented	Within Last Year	1 – 3 Yrs Ago	3 – 5 Yrs Ago	More than 5 Yrs Ago	
a) Accounting						1 2 3 4 5 NA
b) Transportation						1 2 3 4 5 NA
c) Warehousing						1 2 3 4 5 NA
d) Manufacturing/Operations						1 2 3 4 5 NA
e) Inventory Management						1 2 3 4 5 NA
f) Order Management						1 2 3 4 5 NA
g) Customer Service						1 2 3 4 5 NA
h) Research & Development						1 2 3 4 5 NA

16. The following integrating information systems have been implemented by my company to link functional areas:

a) Enterprise Resource Planning (ERP) 1 2 3 4 5
(Examples include SAP, Oracle, JD Edwards, PeopleSoft)
b) Supply Chain Planning System (SCP) 1 2 3 4 5
(i2Technologies, Manugistics, Logility systems)

17. The following supply chain information systems were implemented:

	Not Implemented	Within 1 Year	1 – 3 Yrs Ago	3 – 5 Yrs Ago	More than 5 Yrs Ago	
a) Enterprise Resource Planning (ERP) (Examples include SAP, Oracle, JD Edwards, PeopleSoft)						1 2 3 4 5
b) Supply Chain Planning System (SCP) (i2Technologies, Manugistics, Logility systems)						1 2 3 4 5

18. To what extent has adoption and implementation of the information technology systems discussed so far resulted in cost savings in each of the following functional areas?

a) Accounting	1 2 3 4 5 NA
b) Transportation	1 2 3 4 5 NA
c) Warehousing	1 2 3 4 5 NA
d) Manufacturing/Operations	1 2 3 4 5 NA
e) Inventory Management	1 2 3 4 5 NA
f) Order Management	1 2 3 4 5 NA
g) Customer Service	1 2 3 4 5 NA
h) Research & Development	1 2 3 4 5 NA

19. The following supply chain information technology systems have either been implemented or are planned to be adopted within one year:

a) Enterprise Resource Planning (ERP)	1 2 3 4 5 NA
b) Product Data Management (PDM)	1 2 3 4 5 NA
c) Customer Relationship Management (CRM)	1 2 3 4 5 NA
d) Automated Quality Control (AQC) system	1 2 3 4 5 NA
e) Computer Aided Design (CAD) systems	1 2 3 4 5 NA
f) Supply Chain Planning (SCP) System	1 2 3 4 5 NA
g) Warehouse Management Systems (WMS)	1 2 3 4 5 NA
h) Manufacturing Execution Systems (MES)	1 2 3 4 5 NA
i) Transportation Management Systems (TMS)	1 2 3 4 5 NA
j) Radio Frequency (RF) systems	1 2 3 4 5 NA
k) Geo-coded Tracking systems	1 2 3 4 5 NA
l) Bar coding technology	1 2 3 4 5 NA
m) Electronic Commerce Technology	1 2 3 4 5 NA
n) Supply Chain Event Management (SCE)	1 2 3 4 5 NA
o) Demand Forecasting Management	1 2 3 4 5 NA

20. Please comment on your experiences with adoption, implementation, and integration of supply chain information technologies and the level of success in comparison with expectations.

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Part E: Benefits of Supply Chain Information Technology Systems

Please indicate the extent to which you agree with the following statements.

21. Adoption of supply chain information technology systems has provided the following benefits:

a) Reduced the cost of placing orders with suppliers	1 2 3 4 5 NA
b) Reduced the cost of processing customer orders	1 2 3 4 5 NA
c) Reduced inventory levels	1 2 3 4 5 NA
d) Improved inventory turnover	1 2 3 4 5 NA
e) Improved shipment accuracy	1 2 3 4 5 NA
f) Reduced lead time from receipt of order to delivery	1 2 3 4 5 NA
g) Improved customer service	1 2 3 4 5 NA
h) Increased customer satisfaction	1 2 3 4 5 NA
i) Provides better understanding of our cost to serve	1 2 3 4 5 NA
j) Improved product to market speed	1 2 3 4 5 NA
k) Increased time to product	1 2 3 4 5 NA
l) Improve on-time delivery from suppliers	1 2 3 4 5 NA
m) Provides better distinction of types of inventory (raw materials, work-in-process, finished goods, intransit inventory)	1 2 3 4 5 NA
n) Improved information sharing with suppliers and customers	1 2 3 4 5 NA
o) Improved coordination of logistics activities with suppliers and customers	1 2 3 4 5 NA
p) Increased trust in suppliers and customers	1 2 3 4 5 NA
q) Increased commitment to supply chain relationships	1 2 3 4 5 NA

22. The impact of the implementation of supply chain technology and E-Commerce on the performance of the entire supply chain that my company is a member of has been:

Highly Negative	Somewhat Negative	Neutral	Somewhat Positive	Highly Positive

1 2 3 4 5

23. Please discuss the benefits gained from implementation of supply chain technology and E-commerce in comparison to expected benefits.

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Glossary

The following are examples of the types of supply chain information technology that may help you interpret questions throughout the survey:

Term	Definition
Enterprise Resource Planning (ERP) systems	ERP offers a centralized system to control information flow through a manufacturing environment. ERP covers functions such as capacity planning, cost and accounting, order entry, production management, inventory, and finance. Examples: SAP, Oracle, JD Edwards, PeopleSoft
Product Data Management (PDM)	PDM tools are used to support collaborative engineering. Features such as revision tracking, document workflow, redlining and other tools help make the design engineering and manufacturing process integration easier. Examples: Windchill, Documentum, SDRC
Customer Relationship Management (CRM)	CRM is an intelligent relationship management tool that can offer Web-based analytic and operation systems to unify all inbound and outbound sales, service, and marketing customer interactions. With a single enterprise-wide view of each customer, CRM solutions analytically help a company better understand and proactively serve customers in real time. Examples: Siebel, Vantive
Automated Quality Control (AQC) systems	AQC Systems help monitor quality assurance process, inspection procedures, specifications, and gauge calibration statistics. Examples: Power Way, Pilgrim Software
Computer Aided Design (CAD) systems	CAD systems are generally stand-alone design tools. CAD tools are used to design everything from parts to tools and fixtures. Examples: AutoCad, PTC
Supply Chain Planning (SCP) systems	SCP systems, such as supply and forecasting planning, demand planning, and advance planning and scheduling (APS), are applications that coordinate limited material and capacity resources in accordance with business dynamic changes. These systems deal with strategic and tactical planning issues that generally have long time spans. Examples: i2, Manugistics, Logility

Warehouse Management Systems (WMS)	WMS track and control the movement of inventory through the warehouse, from receiving to shipping. WMS manages utilization of resources such as space and personnel. It also offers systematic management of material handling to optimize and shorten fulfillment cycle time reducing cost. Examples: Catalyst, EXE, Manhattan, Optum
Manufacturing Execution Systems (MES)	MES software provides a single flexible platform for managing customer orders through multiple plants and processes. MES software can deliver real-time visibility and control of manufacturing operations from equipment, materials, and people to the manufacturing processes. It assists companies in responding effectively to unexpected customer requirement changes. Many MES packages offer Internet capability, which offers the visibility and control of production system to suppliers and customers. Examples: CAMSTAR, CINCOM, Intellution, Kronos
Transportation Management Systems (TMS)	TMS are intended to achieve enterprise-wide load control centers by allowing companies to address the complex requirements of transportation between channel partners. TMS solutions can offer sophisticated planning algorithms to optimize different shipping scenarios. Examples: i2, Manugistics, Descartes, nPassage, Capstan
Radio Frequency (RF) systems	Technology or tools that support wireless communication to read and transmit data from data points such as bar codes. Example: NORAND, Intermec, Symbol
Geo-coded Tracking systems	Satellite or cellular tracking devices most commonly used in trucks or trailers to ascertain position and feed the information to ancillary systems such as TMS, Routing or WMS. Examples: Qwest
Bar coding technology	Systems or products that are used in conjunction with any of the above systems to produce bar codes for any purpose. Example: Intermec, NORAND, Zebra Technologies, Symbol
Electronic Commerce Technologies	Technologies that enable computer-based business transactions via private, proprietary networks such as EDI or the publicly accessible internet.

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